11 Accidental Releases

11.1 Introduction

This section assesses the risk of a maximum foreseeable accidental hydrocarbon release occurring from the Kyla Development well and the potentially significant environmental and socio-economic effects that could occur as a result. It also details the control and mitigation measures that will be implemented to both reduce the risk of an incident occurring and limit the potential impacts in the event that a spill did occur. It should be noted that in planning its activities, a primary focus of Serica is to ensure that all practicable measures are taken to prevent the occurrence of accidental events and, should they occur, mitigate their effects. The risk of an accidental release of hydrocarbons occurring from the Kyla Development well will be minimised through the implementation of physical barriers such as safety valves, maintenance to minimise leaks, and the implementation of handling and operational procedures and training to influence human behaviours. Measures to respond to a spill from the Kyla field if an incident did occur will be covered in an OPEP, approved by the Offshore Major Accident Regulator (OMAR) under The Merchant Shipping (Oil Pollution Preparedness, Response and Cooperation) Regulations 1998 (as amended) in advance of the proposed development operations commencing.

11.2 Sources and Likelihood of Accidental Releases

11.2.1 Kyla Hydrocarbon Release Scenarios

The following is a list of potential hydrocarbon release scenarios associated with the Kyla Development well:

- Uncontrolled well blowout;
- Diesel spillage from MODU or vessel;
- Pipeline rupture and subsequent release of liquid hydrocarbon inventory to sea.

The likelihood of these unplanned events occurring is discussed below, using the Likelihood of Occurrence criteria defined in Section 5.3.2.

Likelihood of a Well Blowout

A blowout is an extremely rare event where total failure of all control systems and related processes can result in an uncontrolled release of oil or natural gas (or a mixture of the two) as a result of BOP failure.

Following the 2009 Montara and the 2010 Deepwater Horizon/Macondo well control incidents, EU Directive 2013/30/EU on the safety of offshore oil and gas operations came into force, which is implemented in the UK through the Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations 2015 (SCR 2015). The main aim of SCR 2015 is to reduce the risks from major accident hazards, such as a blowout, to the health and safety of the workforce employed on offshore installations or in connected activities. In addition, SCR 2015 also aims to increase the protection of the marine environment and coastal economies against pollution and ensure improved response mechanisms in the event of such an incident.

Table 11.1 presents North Sea blowout frequencies for various development, production and well intervention activities which are relevant to the proposed Kyla Development. This indicates that for development drilling (for an oil well), the blowout frequency is extremely low at 3.4×10^{-5} per annum for an oil well.

In summary, given the above, the likelihood of a blowout occurring at the Kyla field is considered to be **Extremely Rare**.

An uncontrolled and unmitigated well blowout scenario is considered to result in the largest, volume of hydrocarbons released to sea from the proposed Kyla Development well (a cumulative release of 867,860.89 m^3 of 37.8°API crude oil over a period of 132 days) and has therefore been subject to oil

spill modelling and assessed in the following sections. The Kyla oil spill modelling study is presented in full in Appendix F and a summary of the modelling parameters and key results are detailed below in Section 11.3.2. Of note, the modelling has been completed in line with the OPRED Guidance Notes for Preparing OPEPs for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022).

Table 11.1: Blowout Frequencies (data from IOGP, 2019)

Operation	Well Category	Frequency, Average Well	Frequency, Gas Well	Frequency, Oil Well	Unit
Development Drilling	Normal	3.9×10^{-5}	4.2×10^{-5}	3.4×10^{-5}	per drilled well
Completion	-	2.1×10^{-4}	2.8×10^{-4}	1.4×10^{-4}	per operation
Workover	-	3.0×10^{-4}	4.0×10^{-4}	2.0×10^{-4}	per operation
Producing Wells Note 1	-	3.7×10^{-5}	7.2×10^{-5}	2.1×10^{-5}	per well year

Note 1: Excludes external causes such as ship collisions

Likelihood of a MODU or Vessel Collision

During the Kyla Development there is the potential for a MODU and/or vessel collision, resulting in the entire loss of diesel (fuel oil) inventory (which is typically around 3,500 m^3 for a semi-sub MODU). The risk of collision will be highest when the MODU is on location at Kyla, although shipping densities are low in the area. A vessel traffic survey (VTS) will be undertaken to inform the CtL permit application, which is required to site the MODU and subsea infrastructure at the Kyla location. A CRA may also be undertaken if considered necessary.

In addition, information on the location of the MODU, 500 m safety zone, subsea infrastructure and vessel operations will be communicated to other sea users (via the United Kingdom Hydrographic Office (UKHO)) through the standard communication channels including Kingfisher, Notice to Mariners and Radio Navigation Warnings.

The pipeline laying vessels could pose a short term obstruction to shipping and navigation. However, the vessels will be moving continually along the proposed pipeline route during the installation period so any obstruction will be of very short duration and long term exclusion from any one area will not occur. Vessels involved in installation operations will also update their marks, lights and navigational status broadcast on AIS to indicate to other vessels when they are restricted in manoeuvrability. This will assist any passing vessels that encounter the installation vessels. In addition, in the event that pipelay operations are ongoing when the MODU is on location at the Kyla Development well, a Simultaneous Operations (SIMOPS) plan will be developed to reduce the potential for a collision incident to occur.

Given the above, the likelihood of a MODU or vessel collision is considered to be **Unlikely**. As the loss of diesel inventory is small compared to the well blow out scenario, it is not considered further in this assessment.

Likelihood of a Pipeline Rupture

Accidental releases of hydrocarbons from subsea pipelines are most likely to occur as a result of structural failures of equipment (i.e. internal corrosion for rigid pipelines and stress corrosion cracking for flexible pipelines). Releases due to impact damage are considered rare.

Table 11.2 details the number of Loss of Containment (LOC) events for hydrocarbon pipelines, risers and jumpers on the UKCS during a 20-year period from 2001 to 2020, with an estimate of LOC frequencies for operating pipelines outside of the 500 m safety zone provided in Table 11.3.

Table 11.2: Number of LOC Events (2001-2020) (PARLOC, 2024)

Pipeline Type	Number of LOC Events 2001-2020		
	Pipeline (excluding jumpers)	Risers	Jumpers
Rigid	16	6	7
Flexible	9	4	11

Table 11.3: Estimated Pipeline Loss of Containment Frequencies (PARLOC, 2024)

Pipeline LOC frequencies outside the 500 m safety zone of a production installation for different pipeline lengths					
Pipeline length (per km-year)	0 km to 3 km	3 km to 10 km	10 km to 30 km	30 km to 100 km	>100 km
Rigid Pipeline	4.3×10^{-4}	4.3×10^{-4}	7.7×10^{-5}	1.8×10^{-5}	1.1×10^{-5}
Flexible Pipeline	1.1×10^{-3}				No data

For rigid pipelines in the 10 km to 30 km length category—representative of the proposed Kyla pipeline system, the estimated LOC frequency is 7.7×10^{-5} per km-year, indicating an extremely unlikely event to occur.

The largest release scenarios would involve the loss of containment of the entire inventory of the pipeline; however these types of events are rare. Data from the Worldwide Offshore Accident Database (WOAD) for the period from 1970 to 2007 indicates that worldwide there have only been two major accidents resulting in the total loss of inventory from a pipeline. Both of these events were recorded in the North Sea (Europe), during transfer operations and involved 'loss of buoyancy or sinking' (OGP, 2010).

In summary, the likelihood of a pipeline rupture is considered to be **Extremely Rare.** Significant leakage is estimated to be a short-term event, occurring over a period of a day(s). The total volume of oil released is considerably less than the well blowout scenario which has been modelled and is therefore not considered further in the impact assessment.

It is acknowledged that the Kyla production pipeline and gas lift line also include gas, which would be released in the event of a pipeline rupture. This would result in the increased concentration of greenhouse gas (GHG) emissions in the atmosphere, further contributing to the effects of climate change, and could cause short term air quality impacts. The potential environmental effects from gaseous emissions generated from the Kyla Development are discussed in Section 9 of the ES and have not been considered further in this Section given the unlikely and one-off nature of a pipeline rupture event.

11.3 Fate of Spills in the Marine Environment

11.3.1 Oil Properties and Weathering Processes

When oil is spilled at sea it normally spreads out and moves on the sea surface with the wind and currents. At the same time, a number of natural processes take place; collectively termed weathering, these processes change the physical and chemical properties of the oil and determine its fate in the marine environment. The weathering of oil depends on the chemical and physical properties of the oil (e.g. density, viscosity, wax content and pour point), the weather conditions (e.g. wind, waves, temperature and sunlight) and the properties of the seawater (e.g. salinity, temperature and bacterial flora).

The ITOPF has ranked oils according to their physical characteristics (API/SG) and likely spill behaviour (Table 11.4). The hydrocarbon present in the Kyla reservoir is predominantly going to resemble an ITOPF Group 2 crude oil (based on a density of 0.8365 g/cm^3 @ 15°C and API of 37.8°) that does not form a stable emulsion (refer to Appendix F.6.3). Light crude oils such of these are more susceptible to evaporation and oxidation and consequently reduce faster over time compared to heavier oils.

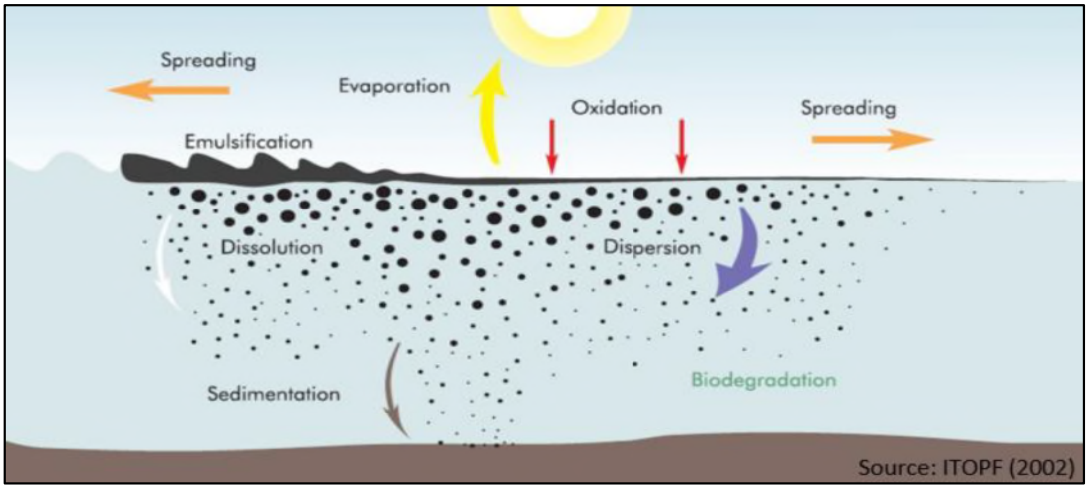
Table 11.4: ITOPF Categories and Characteristics

Group	Specific Gravity	API	Viscosity (cSt)	Typical Examples	Scale
1	< 0.8	> 45˚	< 3	Gasoline products	Light
2	0.8 - 0.85	35˚ - 45˚	4 (semi solid)	Diesel-like products, light crude	
3	0.85 - 0.95	17.5˚ - 35˚	8 (semi solid)	Medium crude, North Sea crude (e.g. Forties)	
4	> 0.95	< 17.5˚	1,500 (semi solid)	Heavy crude and residual oils	Heavy

There are eight main oil weathering processes: spreading, evaporation, dispersion, emulsification, dissolution, sedimentation, oxidation, and biodegradation. The effects of spreading, evaporation, dispersion, emulsification and dissolution are most significant early on in a spill whilst oxidation, sedimentation and biodegradation are more significant later (Figure 11.1) (ITOPF, 2014b).

Over time, as a consequence of weathering, an oil spill will normally break up and begin to dissipate into the marine environment. Lighter products such as the Kyla crude oil (and diesel) under most conditions, evaporate and dissipate quickly and naturally.

Figure 11.1: Oil Weathering Process



11.3.2 Oil Spill Modelling

Although extremely rare, a well blowout event is considered to be the largest accidental release scenario that could occur at the Kyla Development. Therefore, in order to gain an understanding of the fate of the Kyla crude oil in the marine environment a subsea blowout has been modelled using the OILMAP software. Table 11.5 summarises the blowout scenario information and model setup parameters.

Table 11.5: Summary of Blowout Scenario Parameters (Kyla Development)

Parameter	Summary
Scenario Description	
Scenario type	Subsea well blowout (Kyla Development) with a declining flow rate; relief well assumed required
Volume of oil released	Cumulative release of 5,458,587.90 bbl (867,860.89 m^3) of 37.8°API crude oil, over a period of 132 days (Declining release: 49,857 bbl/day on Day 1; 32,854 bbl/day on Day 132)
Justification for largest release volume	Represents maximum credible blowout volume assuming flow can only be stopped via relief well drilling (132 days)
Hydrocarbon Properties	
Oil type	37.8°API crude oil that does not form a stable emulsion
Modelling analogue	Amended Chayvo #6 crude (ITOPF Group 2)
Key oil properties	Density 0.8365 g/cm^3 @15°C; API 37.8°; viscosity 19 cP @ 0°C / 4 cP @ 15°C; pour point 3°C; wax 7%; asphaltenes 0.15%
Release & Simulation Parameters	
Release depth	90 m (subsurface)
Release duration	132 days
Persistence after cessation	Modelled for 10 days post-release.
Simulation period	142 days
Metocean Inputs	
Sea surface temperature	7°C (winter), 14°C (summer), 9°C (spring), 10°C (autumn)
Wind data	European Centre for Medium-Range Weather Forecasts (ECMWF) - Reanalysis v5 (ERA5); date range: 2019 – 2023.
Current data	HYCOM (HYbrid Coordinate Ocean Model) general ocean circulation model and HYDROMAP hydrodynamic model; date range: 2019 – 2023.
Stochastic Setup	
Number of runs	100 runs per season
Probability grid	1 km × 1 km horizontal; 500 m vertical.
Minimum oiling thresholds	Surface: 0.0003 mm; Shoreline: 0.001 mm; Water column: 1 ppb.

Table 11.5 details the largest release scenario for the Kyla field in terms of both the volume of hydrocarbons which would be released and the duration of the spill (i.e. it assumes a relief well would need to be drilled to bring the well back under control). It should be noted that this is an extreme scenario that assumes the complete failure of all control and preventative measures. In a real situation, steps would immediately be taken to stem the flow of hydrocarbons and in the event of a well control incident bring the well back under control. A counter-pollution response strategy would also be developed and initiated to minimise the impact to the marine environment.

The oil spill modelling has been undertaken with the use of OILMAP, an advanced oil modelling tool developed and licensed by RPS ASA, which provides predictions of the fate and transport of spilled hydrocarbons and calculates the probability of key areas being impacted.

To simulate a range of possible metocean conditions, stochastic results were calculated from over 100 trajectory runs per season. This provides insight into the range of probable behaviours of a potential oil spill in response to varying meteorological and oceanographic conditions in the study area. Stochastic modelling computes surface and subsurface trajectories for an ensemble of many individual cases for each spill scenario. Each individual simulation start time is selected randomly, thus sampling the variability in the wind and current forcing. The stochastic model results that have been reported in the assessment include the following:

- The probability and minimum time for surface oiling (with a minimum thickness threshold of 0.3 µm). A surface thickness 0.3 µm is the minimum threshold identified by the Bonn Agreement Oil Appearance Code (BAOAC) capable of producing a visible rainbow sheen. The 0.3 µm threshold value is required by the OPEP guidance notes (OPRED, 2022) and is the chosen value for when potential significant environmental impacts may begin to occur.
- The probability and minimum time for water column oiling (with a minimum concentration threshold of 1 ppb). A concentration of oil in water above 1 ppb is the minimum threshold identified for screening potential effects on sensitive organisms and socio-economic activity (e.g. seafood production).
- The probability and minimum time for shoreline oiling (with a minimum thickness threshold of 1.0 µm). A shoreline thickness 1.0 µm is the minimum threshold identified for potential effects on socio-economic resource uses, as this amount of oil may conservatively trigger the need for shoreline clean-up on amenity beaches (French-McCay, *et al*. 2011 and French-McCay, *et al*. 2012).

It is important to note that the stochastic modelling results do not represent a single spill event, and instead shows the aggregation of results computed by running the spill scenario multiple times (i.e. 100 times per season) over different weather and metocean conditions.

To analyse single spill scenarios, trajectory modelling was undertaken for each season by extracting the worst case simulation run from the stochastic results. The worst case trajectory simulation was identified by the greatest mass of shoreline oiling at any one location after 142 days. The trajectory modelling enables fates analysis on the released oil over time.

The input parameters and modelling results are presented in full in Appendix F. A summary of the key conclusions has been provided below.

Stochastic Modelling Results

Summary of Results

Table 11.6 summarises the stochastic results for a subsea well blowout in the Kyla field across all seasons, reporting the minimum arrival time and probability of oil to reach land and the territorial waters of nearby countries.

Table 11.6: Summary of Stochastic Modelling Results

Subsea Well Blowout in the Kyla Field					
Spill Scenario / Descriptor: 5,458,587.90 bbl (867,860.89 m^3) of Crude Oil (37.8 °API) released over 132 days					
Season		Winter (December – February)	Spring (March – May)	Summer (June – August)	Autumn (September – November)
Median Crossing [Note 1]					
Median Line	**Surface Oil: Probability and Shortest Time to Reach (Minimum Thickness of 0.3 µm)**				
Netherlands	*Maximum Probability*	41 %	2 %	1 %	17 %
	Shortest Arrival Time	38 days	136 days	129 days	68 days
Germany	*Maximum Probability*	56 %	3 %	1 %	28 %
	Shortest Arrival Time	32 days	111 days	103 days	62 days
Denmark	*Maximum Probability*	83 %	20 %	17 %	83 %
	Shortest Arrival Time	16 days	32 days	37 days	28 days
Norway	*Maximum Probability*	100 %	100 %	100 %	100 %
	Shortest Arrival Time	3 days	6 days	8 days	4 days
Sweden	*Maximum Probability*	54 %	N/A	6 %	69 %
	Shortest Arrival Time	25 days	N/A	71 days	39 days
Median Line	**Subsurface Oil: Probability and Shortest Time to Reach (Minimum Water Column Concentration 1.0 ppb)**				
Netherlands	*Maximum Probability*	53 %	2 %	5 %	68 %
	Shortest Arrival Time	35 days	130 days	112 days	48 days
Germany	*Maximum Probability*	78 %	12 %	6 %	72 %
	Shortest Arrival Time	23 days	108 days	106 days	48 days
Denmark	*Maximum Probability*	91 %	58 %	79 %	100 %
	Shortest Arrival Time	15 days	31 days	36 days	29 days
Norway	*Maximum Probability*	100 %	100 %	100 %	100 %
	Shortest Arrival Time	3 days	5 days	7 days	4 days
Sweden	*Maximum Probability*	74 %	20 %	54 %	100 %
	Shortest Arrival Time	24 days	97 days	64 days	38 days

Landfall [Note 1]					
Predicted Locations	**Shoreline Oil: Probability and Shortest Time to Reach (Minimum Thickness of 1.0 µm)**				
UK					
UK (mainland)	*Maximum Probability*	34 %	39 %	7 %	9 %
	Shortest Arrival Time	53 days	27 days	23 days	30 days
Shetland	*Maximum Probability*	5 %	12 %	3 %	9 %
	Shortest Arrival Time	93 days	62 days	91 days	40 days
Orkney	*Maximum Probability*	8 %	7 %	2 %	5 %
	Shortest Arrival Time	79 days	51 days	87 days	56 days
UK Counties at Greatest Risk [Note 2]					
Aberdeenshire	*Maximum Probability*	34 %	39 %	7 %	3 %
	Shortest Arrival Time	53 days	27 days	46 days	32 days
City of Aberdeen	*Maximum Probability*	28 %	32 %	4 %	7 %
	Shortest Arrival Time	71 days	28 days	51 days	33 days
Kincardineshire	*Maximum Probability*	33 %	32 %	5 %	3 %
	Shortest Arrival Time	64 days	28 days	23 days	30 days
Angus	*Maximum Probability*	29 %	28 %	3 %	2 %
	Shortest Arrival Time	78 days	38 days	74 days	30 days
Fife	*Maximum Probability*	22 %	33 %	2 %	2 %
	Shortest Arrival Time	81 days	41 days	72 days	58 days
International					
Germany	*Maximum Probability*	3 %	N/A	N/A	2 %
	Shortest Arrival Time	56 days	N/A	N/A	83 days
Denmark	*Maximum Probability*	57 %	3 %	2 %	75 %
	Shortest Arrival Time	34 days	101 days	77 days	45 days
Norway	*Maximum Probability*	27 %	2 %	11 %	36 %
	Shortest Arrival Time	32 days	96 days	65 days	47 days
Sweden	*Maximum Probability*	22 %	N/A	2 %	40 %

	Shortest Arrival Time	27 days	N/A	139 days	44 days

Note 1: Shortest arrival time and maximum probability values are not necessarily linked to the same run. The results represent a worst case scenario for each feature based on the analysis of all model runs.
Note 2: A breakdown of the maximum probability and shortest arrival time for each UK County to be impacted by shoreline oil is displayed in Appendix F (Table F.6).

Surface Oiling

Table 11.7 reports the maximum distance that the surface oil slick may occur from the Kyla release location for each of the BAOAC 2 – 5 thresholds. This data is displayed graphically in Figure 11.2.

Table 11.7: Surface Oiling by BAOAC Thresholds

Code	Description – Appearance	Layer Thickness Interval (µm)	Litres per km^2	Max Distance from the Release Location
2	Rainbow	0.30 to 5.0	300 – 5000	909 km
3	Metallic	5.0 to 50	5000 – 50,000	872 km
4	Discontinuous True Oil Colour	50 to 200	50,000 – 200,000	93 km
5	Continuous True Oil Colour	More than 200	More than 200,000	68 km

Surface oiling is predicted to occur predominantly within UK waters, extending eastwards towards the Norwegian Trench and Skagerrak region, with lower-probability patches extending south and southeast under some seasonal conditions. The modelling results indicate a 100 % probability of surface oil, at a minimum thickness of 0.3 µm, crossing the UK / Norway median line in all seasons (Table 11.6; Figure 11.3).

A high probability (up to 83 %) of surface oiling is predicted in Danish waters, while moderate probabilities (up to 56 % and 69 %) occur in German and Swedish waters respectively (Table 11.6). The probability of surface oil entering Dutch waters remains comparatively low (≤41 %) (Table 11.6). Seasonal variability is notable, with the greatest transboundary transport predicted in winter and autumn, reflecting enhanced wind-driven spreading and deeper mixing during these periods.

The minimum transit time for surface oil exceeding 0.3 µm in thickness to leave UK waters is predicted to be 78 hours (3 days), corresponding to oil crossing the UK / Norway median line during winter conditions.

Model outputs predict that only UK waters are likely to experience BAOAC 5 (Continuous True Oil Colour) and BAOAC 4 (Discontinuous True Oil Colour) surface oiling. In contrast, BAOAC 3 (Metallic) and BAOAC 2 (Rainbow) thresholds may be reached within Dutch, German, Danish, Norwegian and Swedish waters (refer to Figure 11.2). Overall, the model predicts that surface oil is most extensive during autumn and winter.

Figure 11.2: Maximum Surface Oil Thickness (Bonn Code)

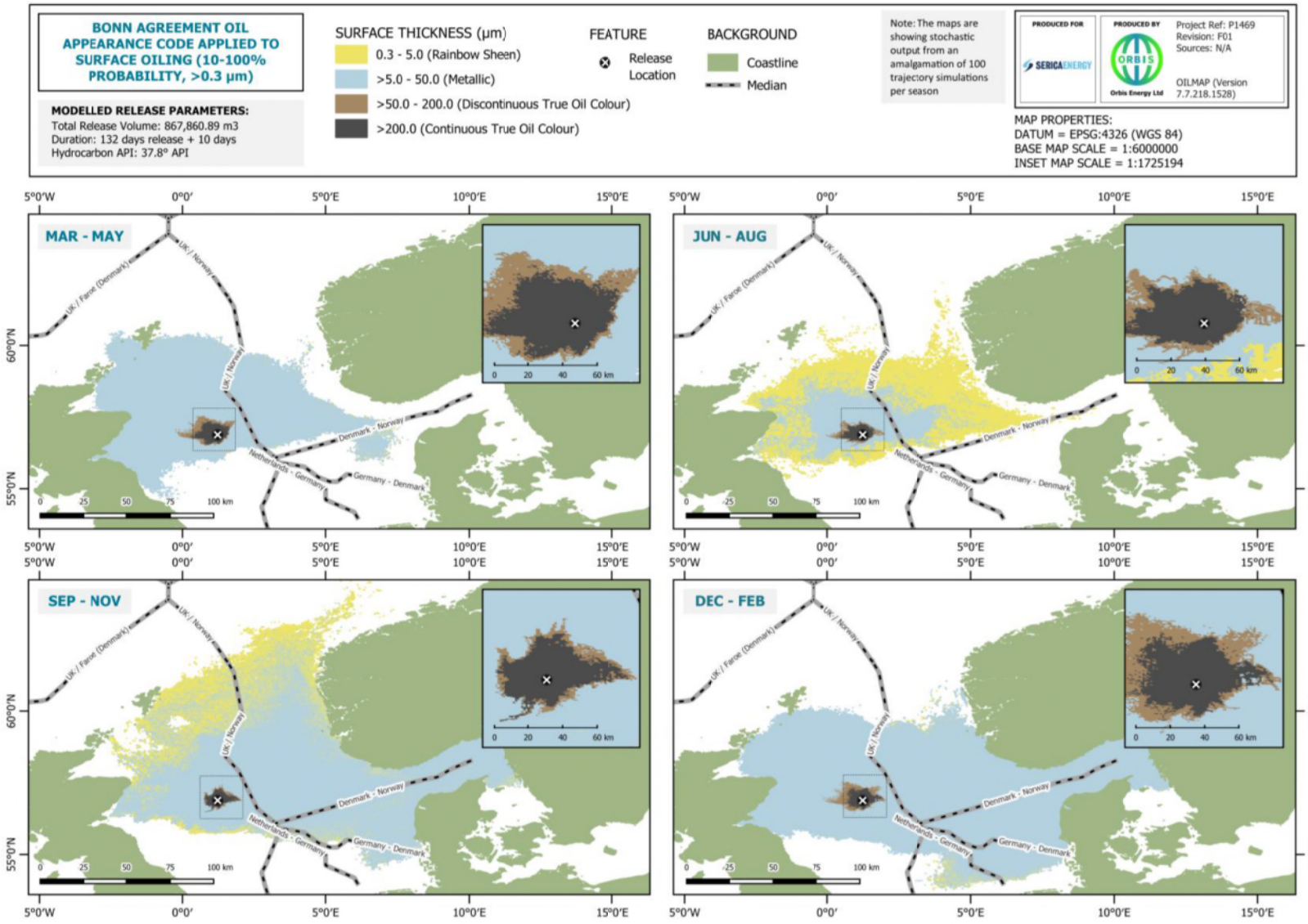
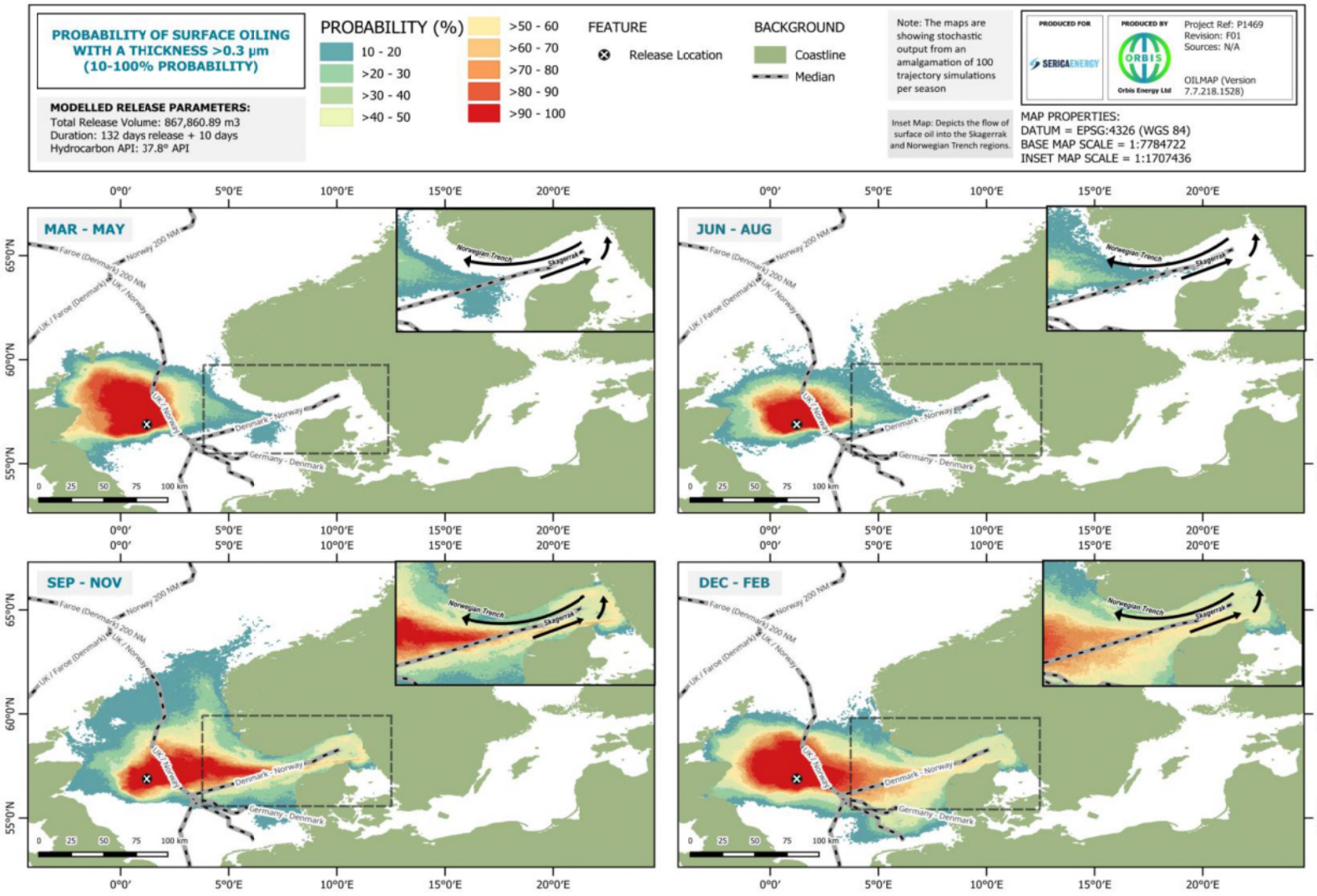


Figure 11.3: Probability of Surface Oiling



Subsurface Oiling

Table 11.8 presents the water column oil concentration thresholds that have been used in the modelling study to help determine subsurface oiling severity in the spatial context.

Table 11.8: Water Column Oil Concentration Thresholds

Threshold for Water Column Oil Concentration (ppb)	Threshold Justification (refer to Appendix F for detailed justification)
1	Screening threshold (Minimum Water Column Concentration modelled) (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, *et al.,* 2012).
70.5	OSPAR recommended predicted no-effect concentration (PNEC) threshold for marine fauna (Smit *et al*., 2009; OSPAR, 2014)

A minimum water column concentration of 1 ppb has been used in the modelling study to determine the probability and minimum time for oiling subsea. This concentration is exceeded out to a maximum distance of 1,366 km from the release location.

Subsurface oiling concentrations are predicted to be highest (>70.5 ppb) over wide areas of the CNS, extending predominantly eastwards and south-eastwards into the Norwegian Trench and Skagerrak region. Elevated subsurface concentrations in the Skagerrak region are attributed to the bathymetric depression and persistent stratification in this area, which can trap and retain hydrocarbons within deeper water layers transported from the North Sea. These oceanographic conditions reduce vertical mixing and promote the accumulation and persistence of oil within the water column (Rodhe, 1996; Danielssen *et al*., 1997; Winther and Johannessen, 2006; OSPAR Commission, 2014; Howarth, 2001) (Figure 11.4). The maximum area at risk of oiling at these higher concentrations is 495,957.80 km^2 at the release location and the surrounding area.

Model results indicate a 100 % probability of subsurface oil, at concentrations exceeding 1 ppb, crossing the UK / Norway median line under all seasonal conditions. There is also a high probability (100 % in autumn) of subsurface oil entering Danish and Swedish waters. Probabilities within German waters range from 6–78 %, while Dutch waters exhibit lower probabilities ranging from 2–68 % (Table 11.6; Figure 11.5).

The minimum time for subsurface oil at a concentration greater than 1 ppb to leave UK waters is approximately 74 hours (3 days), corresponding to oil crossing the UK / Norway median line in winter conditions.

Figure 11.4: Maximum Total Water Column Oil Concentrations

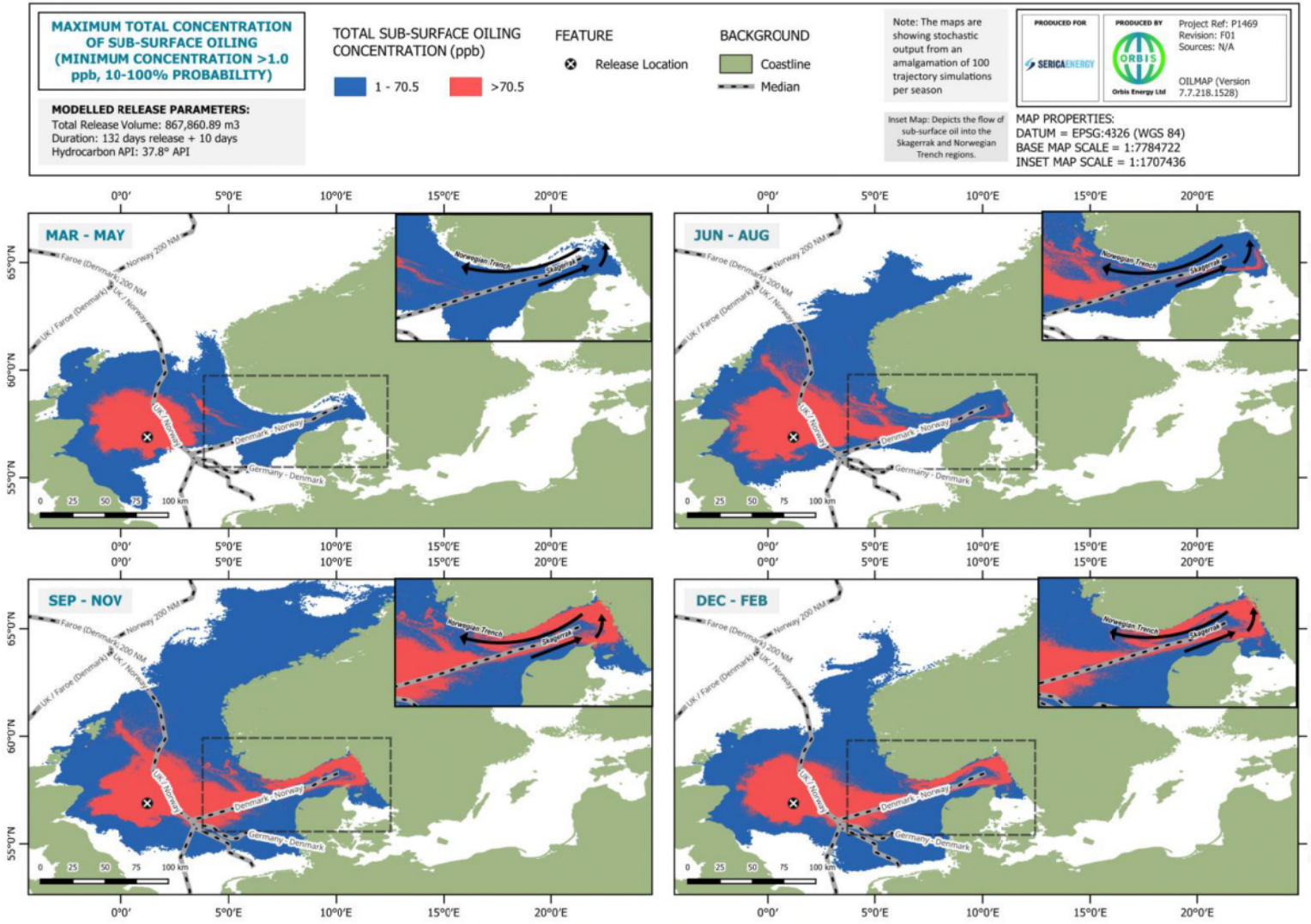
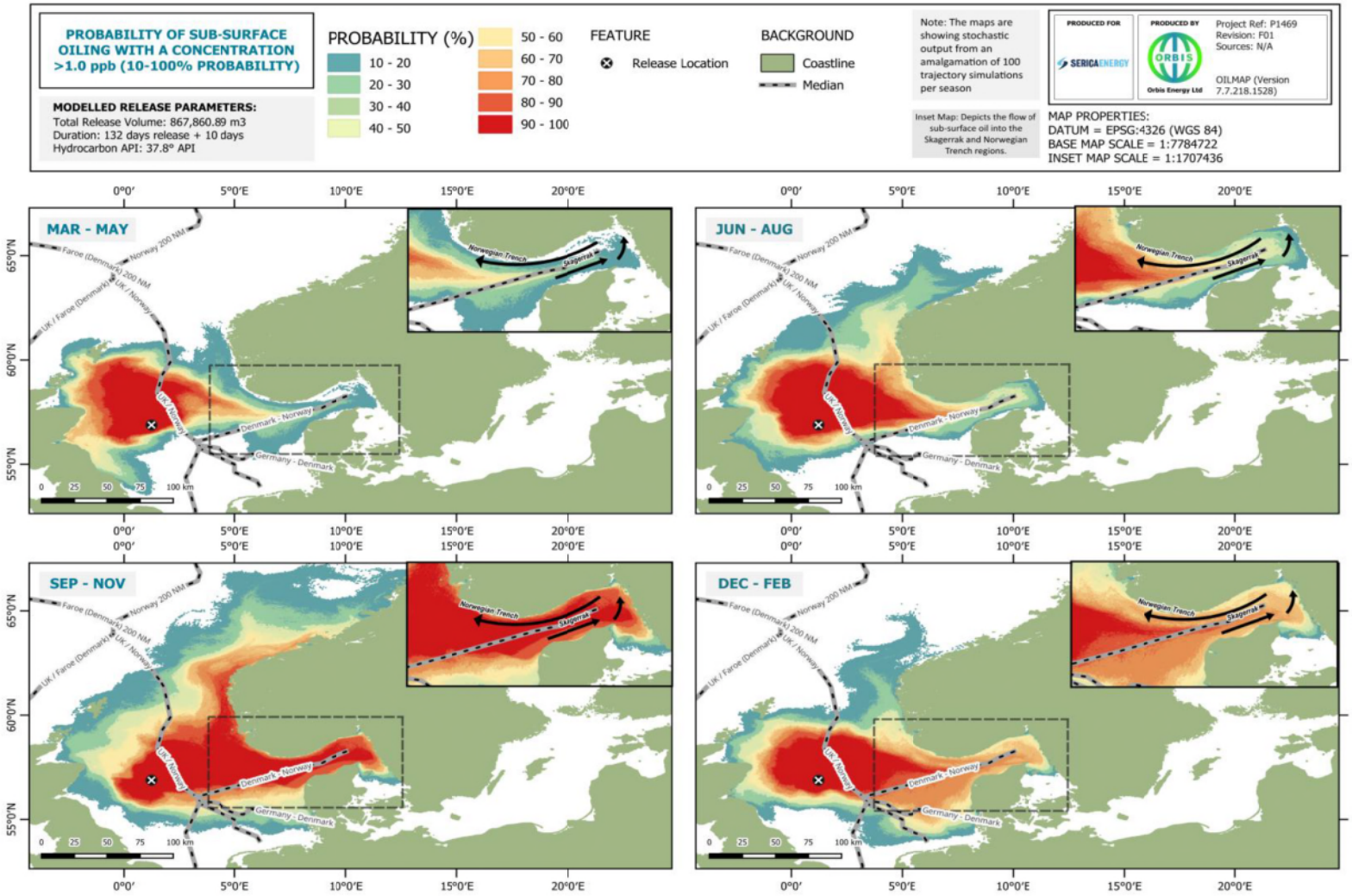


Figure 11.5: Probability of Subsurface Oiling



Shoreline Oiling

Table 11.9 presents the shoreline oiling thickness (and corresponding concentration) thresholds that have been used in the modelling study to help determine shoreline oiling severity in the spatial context.

Table 11.9: Shoreline Oil Thickness Thresholds

Shoreline Oiling Severity (ITOPF, 2014)	Thickness Threshold (mm)	Concentration
Light Oiling	0.001 – <1	0.001 – 1 litres/m^2
Moderate Oiling	1 – 10	1 – 10 litres/m^2
Heavy Oiling	>10	>10 litres/m^2

The stochastic modelling predicts that shoreline oiling could occur along parts of the UK coastline, primarily affecting the northeast of Scotland, with the highest probabilities along the Aberdeenshire and Kincardineshire coasts. The probability of shoreline oiling in UK waters varies seasonally, peaking during spring (up to 39 %) and winter (34 %), with minimum arrival times of 637 hours (27 days) in spring and 1,260 hours (53 days) in winter (Table 11.6). The greatest likelihood of shoreline contact occurs along the Aberdeenshire coast, where modelling indicates moderate shoreline oiling thickness thresholds are reached. Adjacent coastlines such as Angus, Fife, and the City of Aberdeen exhibit lower probabilities (typically 28–33 %) with light to moderate oiling severity. Further south, the probability of oil reaching shore decreases markedly, with only isolated moderate oiling predicted for the Firth of Tay and Firth of Forth areas in spring and winter. No moderate oiling thresholds are predicted for English coastlines (refer to Figure 11.6, Figure 11.7 and Table F.6 in Appendix F for a full breakdown of the UK counties impacted by shoreline oiling).

In northern Scotland, Shetland and Orkney show lower probabilities of shoreline oiling, with a maximum of 12 % and 8 %, respectively, and minimum arrival times of 955 hours (40 days) (Shetland) and 1,219 hours (51 days) (Orkney). These results indicate that oil reaching the northern isles would likely be weathered and patchy, corresponding to light oiling and limited moderate oiling (Table 11.6, Figure 11.6 and Figure 11.7).

Outside the UK, the stochastic modelling predicts that shoreline oiling could occur across several other countries bordering the North Sea, including the coasts of Denmark, Norway, Sweden, and, to a much lesser extent, Germany, with the probability and severity varying between seasons. The Danish coastline shows the greatest potential for transboundary shoreline contact, with maximum probabilities of 75 % in autumn and 57 % in winter, and minimum arrival times of 1,070 hours (45 days) and 818 hours (34 days), respectively (Table 11.6). Oiling along the north-west Jutland and Skagerrak coasts is generally predicted to be of light to moderate severity. Moderate shoreline oiling is most likely to occur where currents converge along the Hanstholm–Hirtshals section and in shallow embayment's of the northern Kattegat, where residual circulation may retain floating residues (Figure 11.6).

To a lesser extent, shoreline oiling is also predicted for Norway and Sweden, reflecting the north-easterly drift of surface oil through the Skagerrak region. For Norway, probabilities peak at 36 % in autumn, with the shortest arrival time of 762 hours (32 days) occurring in winter (Table 11.6). The severity of oiling along the south-west Norwegian coast, particularly between Stavanger and Fredrikstad, is expected to be light to moderate, reflecting the transport of oil through the Norwegian Trench and Skagerrak. For Sweden, shoreline oiling is predicted in autumn (40 %) and winter (22 %), with earliest arrival times of 643 hours (27 days) and 1,060 hours (44 days), respectively (Table 11.6). These results suggest a seasonal influence, with enhanced eastward transport and limited weathering during the cooler months promoting increased potential for oil to reach the Scandinavian coastlines. The shoreline oiling is predicted primarily along the west coast between Gothenburg and Strömstad, with light to moderate severity thresholds reached (Figure 11.6).

Germany shows the lowest potential for shoreline contact, with probabilities of only 2–3% during winter and autumn and arrival times exceeding 1,351 hours (56 days), indicating delayed and highly weathered oil residues which correspond to light severity oiling (Table 11.6, Figure 11.6 and Figure 11.7).

Figure 11.6: Maximum Shoreline Oiling Thickness

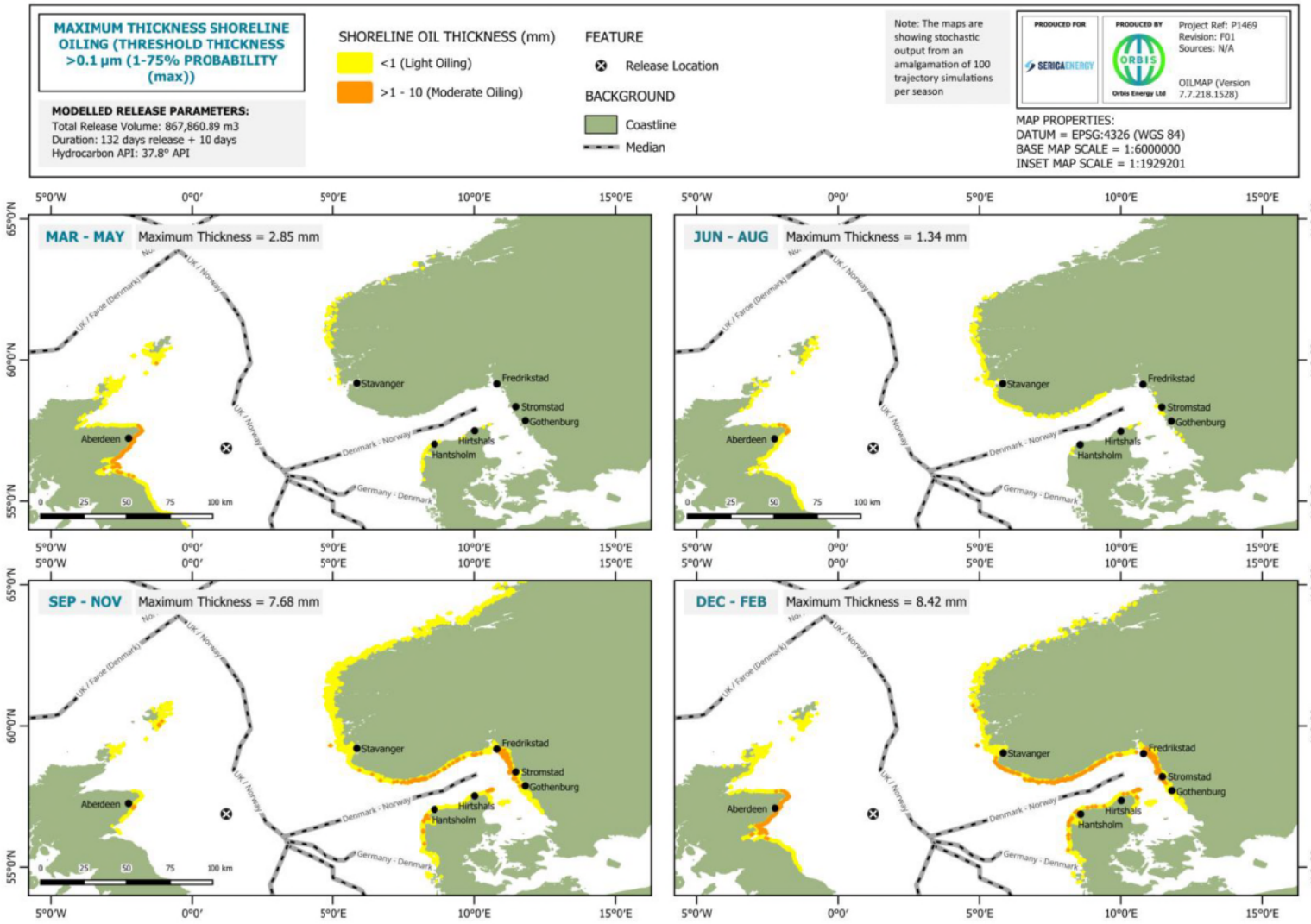
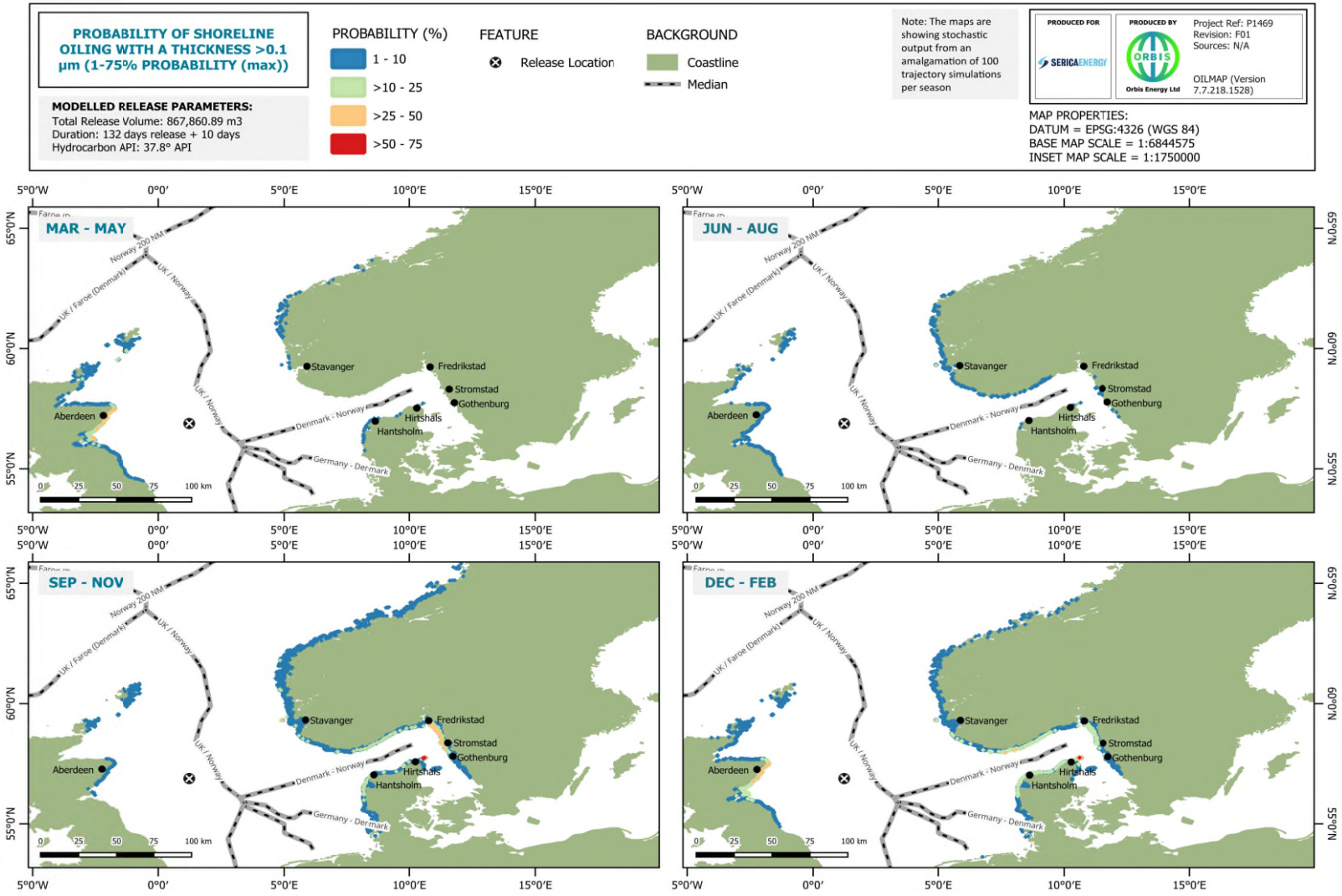


Figure 11.7: Probability of Shoreline Oiling



Worst Case Trajectory Results Summary

Worst case trajectory simulations were identified per season by the greatest mass and volume of oil beached in any one location, as detailed in Table 11.10. The worst case trajectory simulations have been displayed graphically in Appendix F showing the total swept area of surface and shoreline oiling.

Table 11.10: Worst Case Trajectory Simulations Identified from Stochastic Results

Season	Run No	Greatest Mass &Volume of Oil Beached (in any one location)			Sim Start Date	Sim Start Time	Time (hrs) to Impact
		tonnes	m^3	bbl			
Winter	33	10,225.81	12,030.36	75,662.67	03/12/2019	00:00	982
Spring	52	2,237.48	2,632.33	16,555.53	19/03/2021	15:00	1,485
Summer	81	519.96	611.72	3,847.28	05/08/2023	23:00	2,187
Autumn	34	6,096.93	7,172.86	45,112.32	08/11/2019	09:00	1,512

Table 11.11 provides summary statistics for each of the worst case trajectory simulations. It can be seen from this that the maximum surface slick area ranges between 6,772 – 21,840 km^2 across all seasons, although this is short lived due to relatively high evaporation rates.

The fate of released oil after 142 days is consistent between seasons. The released oil does not persist in the marine environment with the majority evaporated (40.15 – 44.25 %) and degraded (38.11 – 41.77 %) after 142 days. A lower proportion (16.50 – 17.63 %) of released oil remains in the water column after 142 days. The trajectory simulations predict very low percentages of oil ashore (0.05 – 0.88 %) and on the sea surface (0.02 – 0.68 %), and zero oil in the sediment after 142 days (refer to Table 11.11).

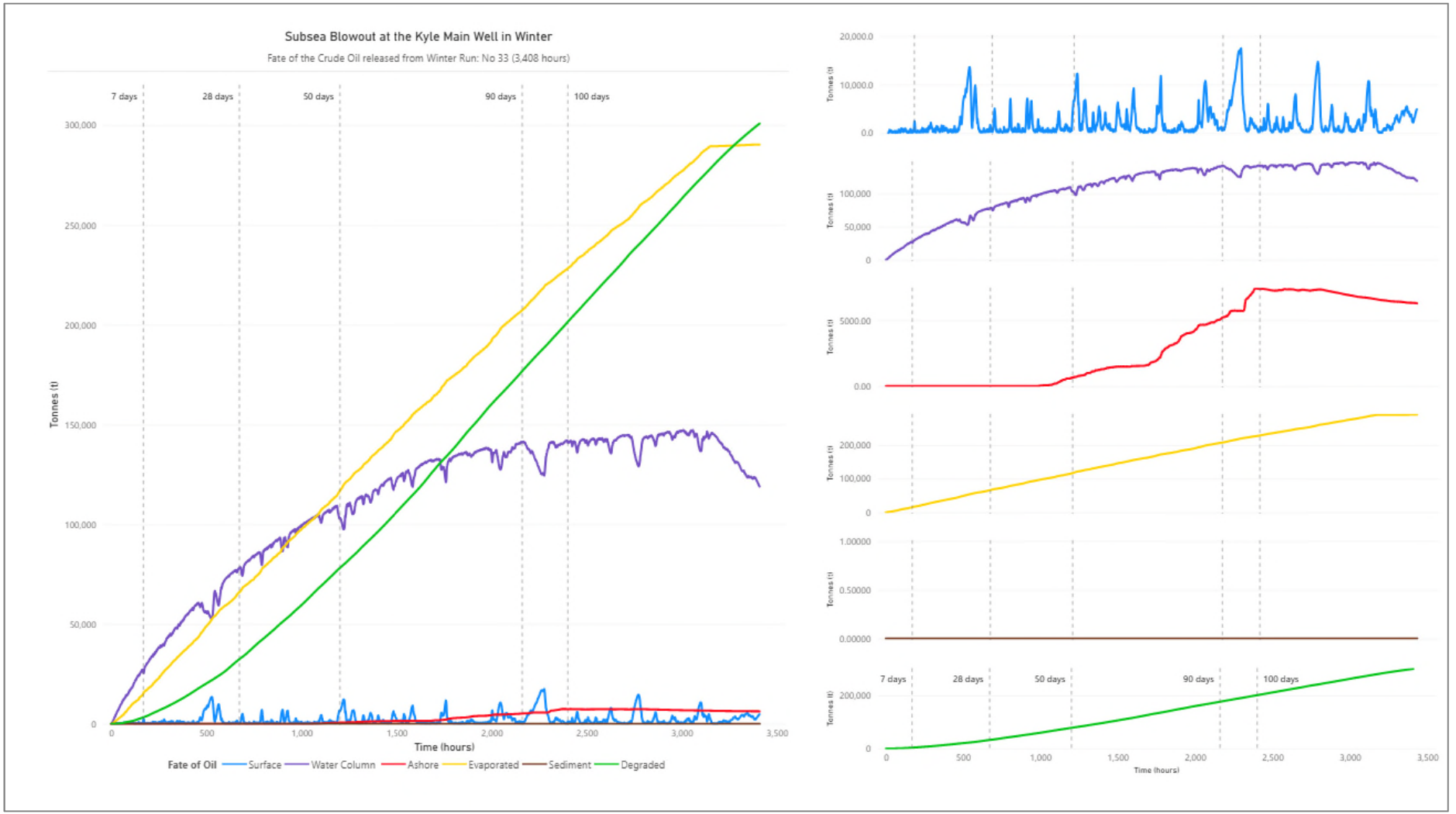
Figure 11.8 depicts the temporal fate (mass balance) of the released oil for the winter trajectory, the worst case season for shoreline oiling. At no point does surface oil exceed 17,417 tonnes, and the water column fraction remains below 147,248.2 tonnes.

The seabed sediment is subject to an undetectable amount of oiling during the spill duration.

Table 11.11: Fate Analysis Summary for Trajectory Simulations

Season	Trajectory Run No.	Minimum Time for Surface Oiling	Maximum Surface Slick Area	Minimum Time for Shoreline Oiling	Impacted Length of Coastline after 142 days	Fate of Released oil after 142 days (% of total release)					
						Ashore	Surface	Water Column	Evaporated	Degraded	Sediment
Winter	33	2 hrs	21,840 km^2	643 hrs	617 km	0.88	0.68	16.50	40.25	41.70	0.00
Spring	52	2 hrs	14,035 km^2	637 hrs	206 km	0.20	0.25	17.19	44.25	38.11	0.00
Summer	81	2 hrs	6,772 km^2	561 hrs	68 km	0.05	0.11	17.63	42.15	40.06	0.00
Autumn	34	2 hrs	13,926 km^2	710 hrs	395 km	0.58	0.02	17.35	40.27	41.77	0.00

Figure 11.8: Fate of the oil released from Winter Run No. 33 (showing model duration 142 days)



Vertical Profile Modelling

Vertical profile modelling (Appendix F, Section F.5) was undertaken using the OILMAP Deep module to simulate the near-field plume behaviour and far-field water column transport of oil released during a subsea blowout in the Kyla field. It is important to note that the near-field plume represents a highly localised zone of turbulent jet mixing, typically on the metre-scale, whereas the far-field model represents the wider, kilometre-scale transport and dispersion of oil droplets under varying current and seasonal conditions.

The near-field plume represents the region immediately surrounding the blowout release where jet momentum and buoyancy control initial rise. The OILMAP Deep results show the initial near-field plume rises to a termination height of 89.55 m (reaching near the sea surface) in 33 seconds, with a maximum plume radius of ca. 6.6 m (maximum width ca. 13 m). The peak oil concentrations are predicted at the plume core on the order of ca. 41,000–44,000 ppb. Beyond this narrow near-field zone the plume transitions to the far-field model, where oil droplets fallout, ambient shear and advection dominate and lead to rapid dilution and lower oil concentrations over much wider areas.

The far-field model considers the buoyant rise of oil droplets through the water column under the influence of stratification, turbulence, and ambient currents. The results indicate that the highest oil concentrations (>10,000 ppb total hydrocarbon concentration) occur only in the immediate vicinity of the release location (within a few kilometres). These elevated concentrations are associated with larger oil droplets (>200 µm) that rapidly rise to the surface within a few hours of release. Smaller droplets (<200 µm), which account for approximately 61 % of the released oil, remain entrained within the water column for longer periods, resulting in a wider area of low-level hydrocarbon exposure. The smallest droplets (<70 µm), representing roughly 16 % of the oil, are predicted to remain in suspension and do not surface, consistent with observations of blowout behaviour (Spaulding *et al*., 2017) and with experimental modelling studies completed in the North Sea (Johansen *et al*., 2013; SINTEF, 2014).

While the vertical profile modelling provides a useful representation of near-field plume dynamics for a single deterministic trajectory, the broader stochastic modelling (refer to Figure 11.4) indicates that elevated subsurface oil concentrations (above the OSPAR PNEC threshold >70.5 ppb) may extend over a wider area of the North Sea under varying seasonal and hydrodynamic conditions. This reflects the influence of changing current regimes, stratification, and droplet size behaviour across multiple simulated release events. Nevertheless, the vertical profile (trajectory) model is useful in demonstrating that the highest oil concentrations remain predominantly within the upper water column and are most pronounced in the vicinity of the release location (refer to Appendix F, Section F.5.3). This result is consistent with findings from other blowout studies (Johansen *et al*., 2013; Spaulding *et al*., 2017; SINTEF, 2014) which show that under North Sea thermohaline and current conditions, the buoyant rise of oil droplets combined with density stratification restricts the extent of subsurface plumes, concentrating hydrocarbons in the near-surface and mid-water layers. This pattern is replicated in the Kyla oil spill modelling, with elevated oil concentrations largely limited to the top layers of the water column and declining rapidly with distance and depth due to dilution, biodegradation, and natural dispersion processes.

These results collectively indicate that while the near-field plume exhibits the highest localised concentrations, the far-field water column exposure on the regional-scale is subject to much lower oiling concentrations which are transient in nature.

11.4 Environmental and Socio-Economic Effects

The potential effects of spills on the marine environment depend on the nature and volume of the hydrocarbons spilt, the extent of weathering in the marine environment, and the sensitivity of the species exposed to the spill (ITOPF, 2014b). Oil spills can affect the marine environment directly through physical smothering of marine organisms and toxicity impacts, and also indirectly through loss of habitat, shelter, or key species in communities, altering community structure and loss of prey (ITOPF, 2014b). The marine environment is highly dynamic and complex. Many species are exposed to fluctuating environmental conditions and therefore have a degree of intrinsic tolerance to environmental stressors, including pollution. However, chronic stressors can reduce the resilience of individuals and communities.

In addition, economic losses can be experienced by industries and individuals dependent on offshore or coastal resources. Usually, the tourism and commercial fisheries sectors are where the greatest impacts are felt (ITOPF, 2014c).

Given the variety of factors that can affect the behaviour of spilt hydrocarbons, accurate predictions of effects before a spill has actually occurred are difficult to make. However, a summary of the potential effects that could occur in the event of a blowout release from Kyla has been provided below based on the oil spill modelling results (refer to Section 11.3 and Appendix F) and the known environmental and socio-economic sensitivities present in the area. In this assessment, to enable a worst case assessment, it is assumed that no response or clean-up activities are implemented to mitigate the spill, noting in reality that this would not be the case.

11.4.1 Water Quality

There is the potential that a release of hydrocarbons from the Kyla field could result in damage that would significantly adversely affect the ecological, chemical and/or quantitative status and/or ecological potential, as defined in Directive 2006/60/EC or the environmental status of marine waters as defined in Directive 2008/56/EC.

The Kyla crude is expected to be a light, ITOPF Group 2 non-emulsifying oil (37.8° API) with a pour point of +3°C. Although viscosity increases in cold waters, values are predicted to remain in the tens of centipoise (cP) (i.e. 4–20 cP between 0–15 °C) rather than hundreds or thousands. So, at typical North Sea temperatures (5–14 °C, i.e., above pour point) the oil remains fluid and is amenable to natural dispersion and entrainment, especially for a subsea release where jet turbulence promotes droplet break-up.

Once the oil reaches the sea surface (typically within 2 hours of release), it undergoes rapid weathering: evaporation removes >40 % of the released oil mass due to its light character. Despite this, modelling indicates localised areas of higher surface severity, with BAOAC 5 (Continuous True Oil Colour) and BAOAC 4 (Discontinuous True Oil Colour) predicted up to 68 km and 93 km from the release location, respectively (refer to Table 11.7 and Figure 11.2). The low asphaltene content reduces the propensity for stable emulsification, limiting persistence in the marine environment, as evidenced by the mass-balance trends in Figure 11.8. Worst case trajectory modelling predicts that 10 days after the end of the subsea blowout release, only 0.02 - 0.68 % of the oil spill total released mass (equivalent to ca. 162 - 4,877 tonnes respectively) would remain on the sea surface (Table 11.11).

Modelling results show that the water column would be impacted over a relatively wide area, with a hydrocarbon concentration of 1 ppb exceeded out to a maximum distance of 1,366 km from the release location. The 1 ppb hydrocarbon concentration was used as the minimum screening threshold in the oil spill modelling (refer to Table 11.8). However, although potential effects to sensitive organisms and socio-economic activity may be detectable at a 1 ppb hydrocarbon concentration, mortality to marine fauna is not expected (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, *et al*., 2012). For the assessment of potential effects to marine fauna in the water column, the OSPAR PNEC of 70.5 ppb THC is adopted. This PNEC is derived from the species sensitivity distribution (SSD) approach in Smit *et al*. (2009) and represents the HC_5 (protective for 95% of species). It is applied as a conservative threshold to identify model grid cells where transient subsurface concentrations may pose a risk of whole-organism effects. Modelling predicts that subsurface oiling at higher concentrations (>70.5 ppb) are found over wide areas of the CNS and extend eastwards and south-eastwards into the Norwegian

Trench and Skagerrak region (especially during autumn and winter) (refer to Figure 11.4). The maximum area at risk of oiling at these higher (>70.5 ppb) concentrations is 154,651.23 km^2 during autumn.

In line with expectations for a 90 m subsea blowout release, vertical profile modelling indicates that peak subsurface oiling concentrations occur within the upper water column (between the release depth and the surface), with limited downward penetration due to buoyant rise. This is consistent with North Sea blowout investigations and model intercomparisons (Johansen *et al*., 2013; Spaulding *et al*., 2017; SINTEF, 2014). On this basis, elevated oil concentrations at depth are not anticipated beyond the immediate near-field zone.

Worst case trajectory modelling predicts 10 days after the end of the subsea blowout release, approximately 16 - 18 % of the oil spill total released mass (equivalent to ca. 119,067 – 127,145 tonnes respectively) would remain in the water column (Table 11.11). Further dilution, dispersion and biodegradation would continue to reduce concentrations of oil in the water column over time.

In summary, the sensitivity of water quality to a blowout is considered to be **Medium**. The receptor has a Very High value; however, the CNS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The water quality is subject to rapid refreshment rates and mixing of the water column, coupled with strong wave action on the sea surface. Therefore, the receptor resistance and resilience is Very High to ITOPF Group 2 oil pollution. The magnitude of impact is considered to be **Major**, given the area which will be subject to oiling, although the oil does not persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on water quality due to the blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to water quality from a well blowout is considered to be **Medium**.

11.4.2 Sediment Quality

The oil spill modelling predicts negligible seabed oiling / deposition. The modelled crude oil is light (37.8° API) and was matched as non-emulsifying with low asphaltenes (Appendix F.6.3). As a result, the released oil bulk density remains well below seawater (1.03 g cm^{-3}) and viscosity stays low–moderate at North Sea temperatures, so released droplets are positively buoyant and rise rapidly from the release depth (90 m) towards the sea surface (minimum time to surface oiling = 2 hours). Because the oil does not form stable water-in-oil emulsions, there is no modelled pathway for the density to increase towards neutrally buoyant or sinking conditions; instead, droplets ascend and are then thinned and dispersed by wind and waves. Of note, approximately 16 % of the released oil comprises very small droplets (<70 µm) that do not surface (Appendix F, Section F.5). This fraction remains entrained in the upper–mid water column, where dilution, dissolution and biodegradation reduce concentrations over time; it is transported laterally by ambient currents rather than contributing to seabed deposition or persistent surface accumulation. In summary, the Kyla trajectory simulations predict negligible seabed oiling and no persistent depositional flux to sediments over the model period.

The sensitivity of sediment quality to a blowout is considered to be **High**. The receptor has a Very High value; sediments in the region are uncontaminated and the East of Gannet and Montrose Fields NC MPA designated for the protection of seabed features (ocean quahog (*Arctica islandica*) aggregations) is within 13.4 km of the release location. Any oil interaction with the seabed sediment would be subject to high biodegradation with recoverability in the medium term. Therefore, the receptor resistance and resilience is High to oil pollution. However, the magnitude of impact is considered to be **Negligible**, as the worst case oil spill modelling revealed negligible amounts of sediment oiling throughout the blowout scenario. Effects on sediment quality due to the blowout scenario are therefore assessed as **Negligible**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to sediment quality from a well blowout is considered to be **Low**.

11.4.3 Plankton

Plankton play a key role in marine and aquatic food webs. Changes in the plankton community can have knock-on effects on fauna feeding at higher trophic levels, such as fish, birds and cetaceans (Ozhan *et al*., 2014).

As hydrocarbons can float on the water's surface and disperse within the ocean as it weathers, plankton may be exposed to both floating hydrocarbon slicks and to small, dissolved droplets of hydrocarbon in the water column (Cormack, 1999; Almeda *et al*., 2013). Hydrocarbon slicks can also inhibit air-sea gas exchange and reduce sunlight penetration into the water, both essential to photosynthesis and phytoplankton growth (González *et al*., 2009). Zooplankton at the surface are thought to be particularly sensitive to oil spills due to their proximity to high concentrations of dissolved hydrocarbon and to the additional toxicity of photo-degraded hydrocarbon products at this boundary (Bellas *et al*., 2013). However, the worst case modelling predicts that surface oiling will be transient and short lived, therefore, limiting the exposure to zooplankton at the sea surface.

Studies have shown growth inhibition in phytoplankton at hydrocarbon concentrations of 100,000 ppb. Conversely, lower levels of hydrocarbons, around 100 ppb, have been found to stimulate growth (Harrison *et al*., 1986).

As discussed in Sections 11.3.2 and 11.4.1 above, elevated oiling concentrations are predicted to occur over wide areas of the CNS and extend eastwards and south-eastwards into the Norwegian Trench and Skagerrak region (refer to Figure 11.4). However, the vertical profile modelling (refer to Section 11.3.2 above and Appendix F, Section F.5) shows that peak oiling concentrations (>10,000 ppb) are confined to the near-field and upper water column, declining by orders of magnitude within tens–hundreds of metres and rapidly over time as buoyant droplets rise and disperse. Beyond this zone, water column oiling concentrations are episodic, short-lived, and predominantly in the low concentration range (<100 ppb), limiting the duration and extent of exposure to plankton. On this basis, plankton exposure to harmful oiling concentrations is predicted to be localised and transient, with broader-scale exposure predominantly ≤100 ppb. Therefore population-level effects are unlikely, although short-term, localised sub-lethal effects (e.g., growth/behavioural responses) may occur.

In general, plankton communities have been found to be highly resilient to the effects of spilt hydrocarbons (Abbriano *et al*., 2011) and their high turnover rate and reproduction is sufficient to make up for any losses of eggs and larval stages that may be lost through mortality in the vicinity of a spill (ITOPF, 2014b). The distribution of plankton across the UKCS is generally uniform and widespread such that it is likely that plankton numbers would recover after the impact of an oil spill and most studies have found that there is a rapid return to normal densities and community compositions once oil in water background levels have returned (IPIECA-IOGP, 2015). In addition, there is evidence that some zooplankton (particularly copepods) can sense and actively avoid oiled areas, therefore reducing potential contact with oil (Seuront, 2010). Consequently, the potential for knock-on effects on fauna feeding at high trophic levels is not considered to be significant.

In summary, the sensitivity of plankton to a blowout is considered to be **Low**. The receptor is of Medium value; the plankton community has a regional importance to the North Sea, providing a food source to higher trophic levels in this region. However, the predicted oiling is transient and does not persist; the plankton has high recoverability in the short-term with high reproduction rates. Therefore, the receptor resistance and resilience is Very High to oil pollution. The magnitude of impact is considered to be **Moderate**, as the worst case oil spill modelling predicts elevated oiling concentrations over a wide area of the CNS and into the Norwegian Trench and Skagerrak regions. However, any impacts to the plankton community are predicted to be short term and temporary. Effects on plankton due to the blowout scenario are therefore assessed as **Minor**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to plankton from a well blowout is considered to be **Low**.

11.4.4 Seabed Communities

In response to hydrocarbon exposure, benthic fauna can either move, tolerate the pollutant (with associated impacts on the overall health and fitness), or die (Gray *et al*., 1988; Lee and Page, 1997). The response to hydrocarbons by benthic species differs depending on their life history and feeding behaviour, as well as the ability to metabolise toxins, especially PAH compounds. However, severe oil pollution typically causes initial massive mortality and lowered community diversity, followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993).

As discussed above in Section 11.4.2, modelling predicts that seabed sediments would be subject to a negligible amount of oiling during the spill duration (refer to Figure 11.8). In addition, the vertical profile modelling indicates that peak subsurface oiling concentrations occur within the upper water column (between the release depth and the surface), with limited downward penetration due to buoyant rise. The oil is subject to rapid dispersion and biodegradation upon release, thus limiting the mass of oil reaching and persisting near the seabed. It is therefore anticipated that seabed communities will be exposed to negligible volumes of oil during and after the spill duration. Mass mortality and lowered community diversity to benthic species is not expected.

In summary, the sensitivity of seabed communities to a blowout is considered to be **Medium**. The receptor has a High value, as habitats and species present at the release location are typical of this region of the CNS. The receptor resistance and resilience is High to oil pollution as the oil does not persist and the benthic community does have some tolerance to hydrocarbon contamination and is expected to recover in the medium term. The magnitude of impact is considered to be **Negligible**, as the worst case oil spill modelling revealed negligible amounts of seabed sediment oiling throughout the blowout scenario. Oil in the seabed sediment does not persist and modelling shows immeasurable / undetectable changes in baseline conditions after the model simulation had completed. Effects on seabed communities due to the blowout scenario are therefore assessed as **Negligible**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to seabed communities from a well blowout is considered to be **Low**.

11.4.5 Fish

Fish (including eggs and larvae) may be affected by spilt oil in a number of ways; their gills may be contaminated with oil, planktivorous or piscivorous fish may consume contaminated prey and larvae or eggs may be susceptible to certain toxic and volatile components of oil (Neff, 1990). Free swimming adult fish however, tend to be less susceptible to the effects of an oil spill as they can detect it and move away from the affected area (ITOPF, 2014b). In addition, many fish species have developed systems which can metabolise and excrete aromatic hydrocarbons and therefore most fish do not tend to accumulate high concentrations of petroleum hydrocarbons, even in heavily oil-contaminated environments (Neff, 1990). Hydrocarbons have, however, been detected in fish bile over one year after the Deepwater Horizon oil spill (Murawski *et al*., 2014), suggesting that adult fish may accumulate hydrocarbons after a large hydrocarbon spill event.

Juvenile fish and larvae are susceptible to the toxic effects of hydrocarbons that may cause larval mortality depending on the type of oil and the exposure time (Abbriano *et al*., 2011). Oil spills can result in high mortality, as well as genetic mutations, in fish eggs and larvae which are relatively immobile and are therefore more likely to be exposed to a spill for a longer period of time. Joye *et al*. (2016) reported an estimated 2–5 trillion fish larvae were killed as a consequence of the Deepwater Horizon oil spill.

Studies have shown that fish tainting from oil exposure can occur at oil concentrations from 10 ppb (GESAMP, 1993). Modelling predicts that water column oiling at a concentration >10 ppb could occur at distances up to 1,329 km from the release location (refer to Figure 11.9).

The chemical components of lighter oils, such as the Kyla crude oil, have a high biological availability and toxic impacts are more likely than from a heavy crude. As previously discussed, the OSPAR PNEC (>70.5 ppb) has been applied as a conservative threshold to identify model grid cells where subsurface oiling concentrations may pose a risk of whole-organism (including fish) effects (refer to Table 11.8). It is highly unlikely that mortality to fish will occur close to the 70.5 ppb OSPAR PNEC; however, toxicological effects may be long lasting, and contamination may lead to sub-lethal effects such as impaired feeding and reproduction (ITOPF, 2014b). As previously noted, modelling predicts that

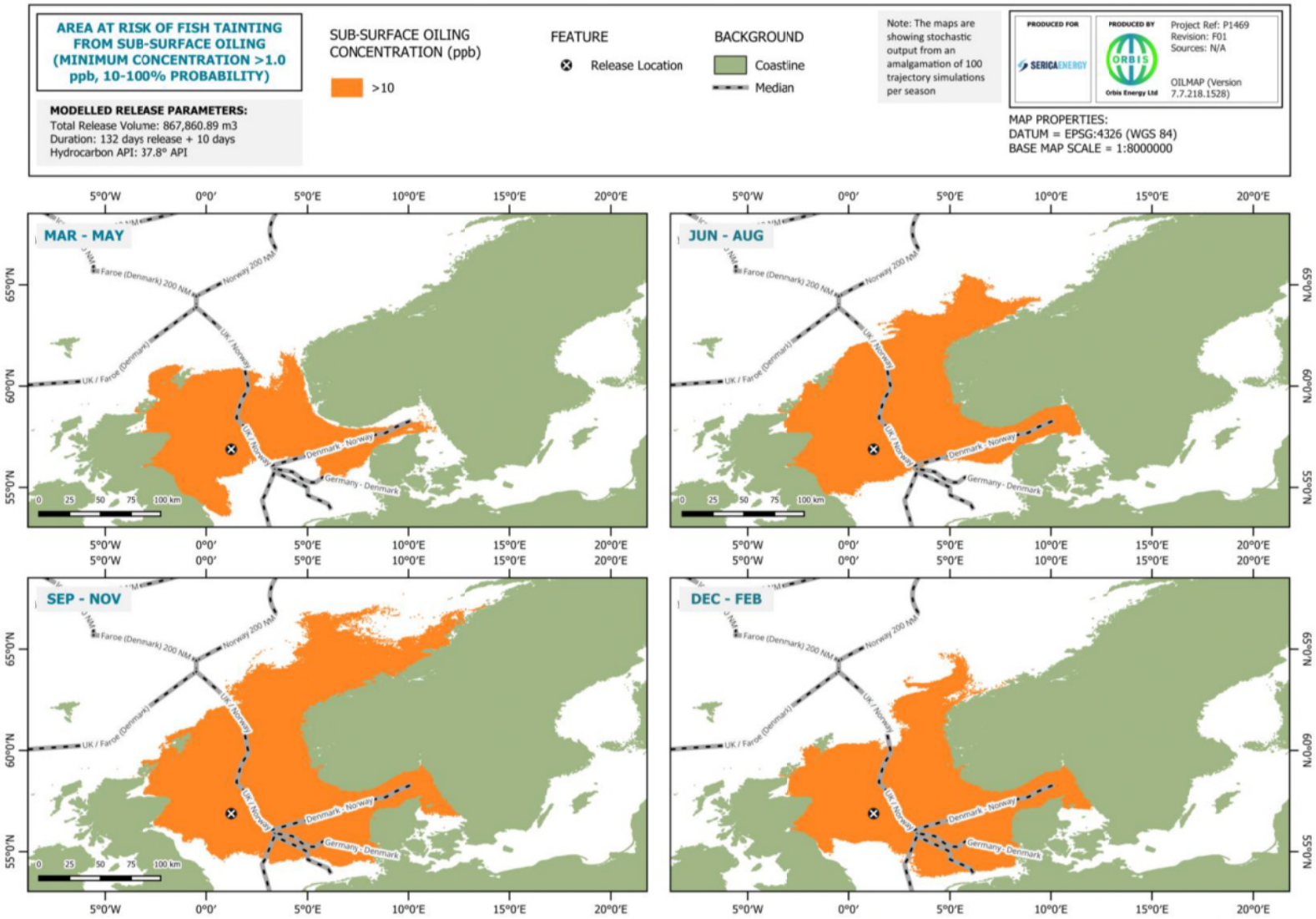
subsurface oiling at elevated concentrations (>70.5 ppb) are found over wide areas of the CNS and extend eastwards and south-eastwards into the Norwegian Trench and Skagerrak region (especially during autumn and winter) (refer to Figure 11.4). The maximum area at risk of oiling at these higher (>70.5 ppb) concentrations is 154,651.23 km^2 during autumn. Of note, the vertical profile modelling results demonstrate that peak subsurface oiling concentrations occur within the upper water column which puts pelagic fish species at greatest risk. However, the subsurface oiling exposure on the regional scale is transient in nature. Once the hydrocarbon disappears from the water column fish generally lose contamination from their tissues quickly due to their ability to metabolise accumulated hydrocarbons very rapidly (Krahn *et al*., 1993).

As noted above, a large release of oil from the Kyla field could also have the potential to impact fish spawning success. The eggs and larvae of broadcast spawners, which are widely dispersed, could be exposed to oil in the water column. Fish species that are demersal spawners are less at risk, as the worst case spill modelling predicts that seabed sediments would be subject to a negligible amount of oiling during the spill duration (refer to Figure 11.8).

There are a number of fish spawning and nursery grounds which either overlap with the Kyla area or are found in the wider area (see Section 4.3.3). This includes the following species listed as PMFs in Scottish waters: anglerfish, blue whiting, cod, herring, ling, mackerel, Norway pout, sandeels, spurdog and whiting (NatureScot, 2022). However, many of these species have a widespread distribution and their spawning and nursery grounds are not restricted to this area. It is important to note that any localised mortality of eggs and larvae following a spill rarely impacts wider populations. Even a large spill, coinciding with a geographically isolated spawning event, would be extremely unlikely to expose a notable proportion of the adult stock to a sustained lethal dose of hydrocarbons (IPIECA-IOGP, 2015). In addition, marine organisms are adapted to acute local impacts by the production of vast surpluses of eggs and larvae, and recruitment from outside the affected area (ITOPF, 2014b; IPIECA-IOGP, 2015).

In summary, the sensitivity of fish to a blowout is considered to be **Medium**. The receptor has a High value; with many species listed as PMF in Scottish waters. However, the oil does not persist and fish do have some tolerance / ability to avoid, adapt and recover from hydrocarbon pollution. Therefore, the receptor resistance and resilience is High to oil pollution. The magnitude of impact is considered to be **Major**, given the wide area which will be subject to oiling, although the oil does not persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on fish due to the blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to fish from a well blowout is considered to be **Medium**.

Figure 11.9: Area at Risk of Fish Tainting (Subsurface Oil Concentration >10 ppb)



11.4.6 Seabirds

The effects of oil on seabirds has been widely studied and includes both immediate chronic impacts which can kill birds or longer-term, sub-lethal, impacts that could affect individuals and populations over many years (e.g. Camphuysen *et al*., 2005; Perez, *et al*., 2009). Seabird species that raft together or spend a significant amount of time on the sea surface (such as auks) are particularly vulnerable to oil spills. A small spill during the breeding season or moulting season, when they cannot fly or where large populations of seabirds have congregated, can prove more harmful than a larger spill at a different area or time of year. Oiling of plumage can result in mortality due to hypothermia, loss of buoyancy and potentially drowning, as well as indirectly by reducing the bird's ability to take off and fly thereby potentially hindering their search for food or escape from predators (ITOPF, 2014b). A seabirds' instinctive response to oiling is to clean itself by preening and ultimately ingesting oil from its plumage. Seabirds may also be indirectly affected through the ingestion of contaminated prey.

The proposed Kyla Development area is located approximately 182 km from the nearest UK coastline and is therefore remote from sensitive seabird breeding areas. However, the following species may forage within the proposed development area during the breeding season: Northern fulmar and black-legged kittiwake (JNCC, 2025; Woodward *et al*., 2019; Woodward *et al*., 2024; RSPB, 2025). Following the breeding season, large numbers of moulting auks, including common guillemot, razorbill (*Alca torda*) and Atlantic puffin disperse from their coastal colonies and into the offshore waters. Kittiwake, Gannet, and Fulmar are also present in sizable numbers during the post breeding season (DESNZ, 2022). An assessment of the median SOSI scores for the UKCS Blocks making up the Kyla Development and wider area shows that the sensitivity of seabirds to oil pollution is low throughout the year (Webb *et al*., 2016) (refer to Section 4.3.4).

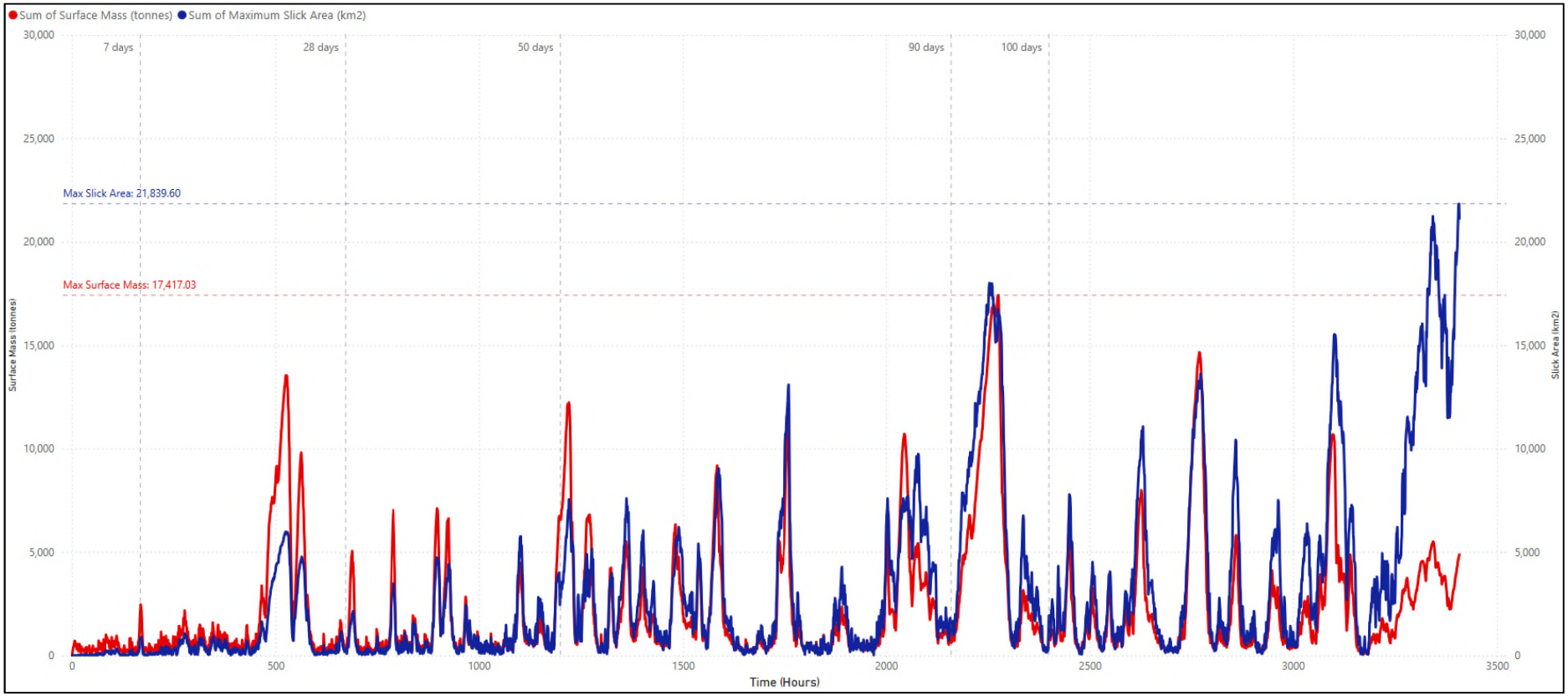
An oil sheen thickness >0.3 µm (BAOAC 2 – Rainbow) is the minimum thickness threshold modelled and has the potential to impact seabirds up to 909 km from the release location. The most severe surface oiling (BAOAC 5 - Continuous True Oil Colour) may occur within 68 km of the release location (refer to Table 11.7 and Figure 11.3). Therefore, in the event of a well blowout in the Kyla field, significant volumes of hydrocarbons may surface over a wide area, potentially affecting a large number of seabirds. Of note, despite being a considerable distance from the release location, 31 SPAs are at risk from surface oiling at BAOAC 3 (Metallic) and BAOAC 2 (Rainbow) thresholds (refer to Section 11.4.8).

Although the stochastic modelling indicates that surface oiling can occur over a wide area and, at times, at higher severity, it is not predicted to persist or accumulate. Figure 11.10 presents the time-series of surface slick area (threshold >100 kg km^{-2}) and surface oil mass for the winter trajectory, run no. 33. The maximum instantaneous slick area is 21,839.6 km^2, and the peaks / troughs reflect the episodic nature of surfacing (time for released oil to reach the sea surface) coupled with rapid evaporation once at the surface. Consequently, the slick grows and decays in pulses throughout the release, limiting the duration of peak surface exposure and the window for interaction with rafting seabirds. However, it must be recognised that even short exposures may still pose a risk to individual birds.

The stochastic modelling predicts that the Shetland Islands and the east coast of Scotland (between Aberdeenshire and Berwickshire) are at risk from 'moderate' shoreline oiling with a maximum thickness of 8.42 mm. The greatest mass of beached oil at any one location is 10,225.81 tonnes. Therefore, seabirds on the shoreline are at risk from a large scale oiling event.

In summary, the sensitivity of seabirds to a blowout is considered to be **Very High**. The receptor has a Very High value; the seabird assemblage in the adjacent coastlines to the Kyla Development area is of international importance. Seabirds that are exposed to oiling have very limited tolerance and recovery is unlikely. Therefore, the receptor resistance and resilience is Low to oil pollution. The magnitude of impact is considered to be **Major** as surface oiling has the potential to impact seabirds up to 909 km from the release location. However, the surface oil is not predicted to persist with high evaporation rates. Effects on seabirds due to the blowout scenario are therefore assessed as **Major**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to seabirds from a well blowout is considered to be **Medium**.

Figure 11.10: Surface Slick Area (with a concentration >100 kg / km^2) and Surface Oil Mass over Time during Winter Run No. 33



11.4.7 Marine Mammals

As discussed in Section 4.3.5, cetacean species most likely to be present in the vicinity of the proposed Kyla Development area include: common dolphin, harbour porpoise, minke whale, white beaked dolphin and white sided dolphin. All cetaceans (whales, dolphins, and porpoises) are listed as EPS under Annex IV of the Habitats Directive. Harbour porpoise is also listed on the OSPAR List of Threatened and/or Declining Species (OSPAR, 2024) and harbour porpoise is listed under Annex II of the Habitats Directive. In addition, harbour porpoise, minke whale and white beaked dolphin are listed as PMFs (NatureScot, 2022). All species listed above are regarded as being of Least Concern in terms of their population threats (IUCN, 2025).

Although marine mammals also use the sea surface in a similar manner to seabirds (refer to Section 11.5.6), they are generally less affected by spills of oil as they can detect and move away from oiled areas (Abbriano *et al*., 2011). Unlike fish or seabirds, oil is also unlikely to adhere to or permeate through the skin of marine mammals where it could accumulate in tissues and have toxicity effects (Neff, 1990). While cetaceans skin is not thought to be particularly sensitive to oil, any accidental ingestion or breathing of oily fumes could cause physiological stress (Takeshita *et al*., 2017). Notably, following the Deepwater Horizon spill in 2010, significant health issues were identified in a resident bottlenose dolphin population located in one of the most heavily oiled area, including pulmonary disease and low reproductive success (Lane *et al*., 2015; Takeshita *et al*., 2017), however, there is still some doubt these effects were directly linked to the spill. Notwithstanding the research conducted after the Deepwater Horizon, current evidence does not suggest more than a low sensitivity to oil for most cetaceans, but resident populations of some species may be both vulnerable and sensitive to large oiling events (Kirby *et al*, 2018).

Both harbour and grey seals are widespread around the adjacent east coast of Scotland (SCOS, 2024). Seals utilising coastal waters, particularly those at haul-out and breeding sites, may be impacted in the event of shoreline oiling. These species rely on their fur to regulate their body temperature which may be hindered if fur becomes matted with oil and may subsequently suffer from hypo- or hyperthermia. Individuals may also be at risk of ingesting oil when cleaning themselves (ITOPF, 2014b). The stochastic modelling predicts that the Shetland Islands and the east coast of Scotland (between Aberdeenshire and Berwickshire) are at risk from 'moderate' shoreline oiling with a maximum thickness of 8.42 mm. The greatest mass of beached oil at any one location is 10,225.81 tonnes. Therefore, seal haul-out sites on the shoreline are at risk from a large scale oiling event.

In summary, the sensitivity of marine mammals to a blowout is considered to be **High**. The receptor has a Very High value as marine mammals are of international importance. However, the oil does not persist and marine mammals have some capacity to avoid hydrocarbon pollution. Therefore, the receptor resistance and resilience is High to oil pollution. The magnitude of impact is considered to be **Major**; given the wide area which will be subject to oiling, although the oil does not persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on marine mammals due to the blowout scenario are therefore assessed as **Major**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to marine mammals from a well blowout is considered to be **Medium**.

11.4.8 Marine Protected Areas

Modelling indicates that a total of 103 UK designated MPAs are at risk to oiling under the blowout scenario. Of these, 54 sites are predicted to be at risk from surface oiling, 48 sites from shoreline oiling, and 89 sites from subsurface oiling within the model domain (Table 11.12).

The greatest number of potentially affected sites are SPAs and SACs, reflecting their extensive distribution across the North Sea and along the UK's north-east coastline. Surface oiling probabilities are generally highest for offshore and nearshore SPAs and NC MPAs in the north-western CNS, with trajectories extending toward Orkney and Shetland. Higher shoreline oiling probabilities are mainly associated with SPAs and SACs around the Orkney, Shetland, and north-east Scotland coasts, with much lower probabilities for sites further south.

All MPAs potentially at risk from surface, subsurface and shoreline oiling are presented in Appendix F (Section F.3.3), where the maximum probability, minimum (shortest) arrival time, and maximum predicted severity are reported for each site. These results provide a detailed breakdown of potential exposure across SPA, SAC, NC MPA, MCZ, and Ramsar designations under the spill scenario.

Table 11.12: Summary of MPAs at risk from Oiling [Note 1]

MPA Designation Type	Total number of sites at risk from Oiling	Number of sites at risk from Surface Oil	Number of sites at risk from Shoreline Oil	Number of sites at risk from Subsurface Oil
SPA	37	31	28	32
SAC	28	8	12	22
RAMSAR	9	2	4	6
NC MPA	17	11	3	17
MCZ	12	2	1	12
Total	**103**	**54**	**48**	**89**

Note 1: Internationally designated MPAs are excluded, as they lie outside UK jurisdiction and conservation obligations, and there is no regulatory requirement to assess feature-level impacts on non-UK conservation designations. Transboundary considerations are addressed separately in Section 11.8.

A summary of the key findings is provided below and in Table 11.13. The assessment focuses on the protected features and qualifying species within designated sites that may be at risk from oiling. In determining potential significance, the assessment considers both the predicted oiling severity and the inherent vulnerability and ecological sensitivity of the designated receptors. The following sections summarise the predicted effects for MPA sites at risk from surface oil, subsurface oil, and shoreline oil exposure.

Surface Oiling

The MPAs most likely to be affected by surface oiling are those designated for the protection of seabird species and marine mammals, as these receptors spend significant time at or near the sea surface where oil accumulates. Although modelling predicts that the surface slicks will be transient and non-persistent, even short-term exposure can compromise seabird plumage and thermoregulation. Seabirds are considered to have 'Very High' sensitivity (refer to Section 11.4.6) and marine mammals 'High' sensitivity (refer to Section 11.4.7) to surface oiling.

Surface oiling with a minimum thickness of >0.3 µm (equivalent to BAOAC 2 or greater) is therefore considered sufficient to cause potential adverse effects to MPAs designated for these taxa. Table 11.13 lists MPAs where surface oiling above this threshold (>0.3 µm) is predicted under the Kyla blowout scenario, together with the qualifying features most vulnerable to surface exposure.

The MPAs designated for qualifying seabird species which are at greatest risk from surface oiling (probability >40 %) include:

- Buchan Ness to Collieston Coast SPA (68 %).
- Fair Isle SPA (48 %).

- Forth Islands SPA (49 %).
- Fowlsheugh SPA (61 %).
- Outer Firth of Forth and St Andrews Bay Complex SPA (59 %).
- Sumburgh Head SPA (41 %).
- Ythan Estuary, Sands of Forvie and Meikle Loch SPA (64 %).

The MPAs designated for qualifying marine mammal species which are at greatest risk from surface oiling (probability >40 %) include:

- Firth of Tay and Eden Estuary SAC (54 %).

Shoreline Oiling

For the purpose of this assessment, moderate shoreline oiling (1–10 litres/m²), as defined by ITOPF (2014a), has been adopted as the threshold at which potential adverse effects to the qualifying coastal or intertidal features of MPAs may occur. Below this threshold (classified as 'light oiling'), surface residues are expected to be thin, patchy and short-lived, with minimal potential for ecological harm once natural weathering and tidal dispersion processes are taken into account. Consequently, the assessment of shoreline effects focuses on sites where moderate or greater oiling severity is predicted, and where qualifying features are considered vulnerable to hydrocarbon exposure under the Kyla blowout scenario. Coastal MPAs designated for seabird colonies and for marine mammals that haul out of the water are considered most at risk from moderate shoreline oiling with 'Very High' to 'High' sensitivity.

Model predictions indicate that moderate shoreline oiling (1–10 litres/m²) could occur along discrete areas of the eastern Scottish coastline, affecting several coastal MPAs designated for seabirds, wintering waterfowl and marine mammals. The sites most at risk include the Buchan Ness to Collieston Coast SPA, Forth Islands SPA, Outer Firth of Forth and St Andrews Bay Complex SPA, Ythan Estuary, Sands of Forvie and Meikle Loch SPA, Firth of Tay and Eden Estuary SAC, and Firth of Forth Ramsar site, where shoreline oiling probabilities range from 13 - 39 %. These sites support large breeding seabird colonies and overwintering birds, extensive intertidal flats and estuarine habitats, and important haul-out areas for grey and harbour seals, all of which are sensitive to hydrocarbon contamination of shoreline substrates. Table 11.13 summarises the MPAs and their qualifying features which are predicted to experience moderate oiling severity.

Subsurface Oiling

The OSPAR PNEC of 70.5 ppb THC has been adopted as the threshold for identifying potential adverse effects to qualifying MPA features. Concentrations above this level indicate the potential for short-term toxic effects in the water column, whereas lower concentrations are not expected to cause harm to marine organisms.

Model predictions show that subsurface oiling above the OSPAR PNEC threshold (>70.5 ppb) occurs primarily in the CNS and northern North Sea, extending eastwards and south-eastwards towards the Norwegian Trench during some seasonal scenarios (particularly autumn and winter). Elevated concentrations are transient and mainly confined to the upper water column, where oil droplets remain suspended before dissipating through advection, dilution, and biodegradation (refer to Appendix F). MPAs designated for pelagic or diving seabirds, marine mammals, and fish species are considered most vulnerable to these subsurface exposures, given their time spent foraging or migrating through mid- to upper-water habitats. Their sensitivity to water column oiling ranges from 'Medium' to 'Very High' (refer to Sections 11.4.5 – 11.4.7).

Table 11.13 lists MPAs where subsurface oiling above the OSPAR PNEC threshold (>70.5 ppb) is predicted under the Kyla blowout scenario. Note, only sites with qualifying features sensitive to hydrocarbon exposure have been included. MPAs designated for seabed or benthic habitats (e.g. East of Gannet and Montrose Fields NC MPA) have been screened out of Table 11.13, as model results show negligible oiling of seabed sediments and therefore no credible risk of hydrocarbon exposure to benthic features (refer to Section 11.3.2).

The MPAs designated for qualifying seabird species which are at greatest risk from subsurface oiling (probability >40 %) include:

- Buchan Ness to Collieston Coast SPA (61 %).
- Fair Isle SPA (71 %).
- Firth of Forth SPA (51 %)
- Forth Islands SPA (67 %).
- Fowlsheugh SPA (57 %).
- Mousa SPA (50 %).
- Northumberland Marine SPA (59 %).
- Outer Firth of Forth and St Andrews Bay Complex SPA (68 %).
- Seas Off Foula SPA (70 %).
- Sumburgh Head SPA (70 %).
- Ythan Estuary, Sands of Forvie and Meikle Loch SPA (61 %).

The MPAs designated for qualifying marine mammal species which are at greatest risk from subsurface oiling (probability >40 %) include:

- Berwickshire and North Northumberland Coast SAC (58 %).
- Mousa SAC (51 %).

The MPAs designated for qualifying fish species which are at greatest risk from subsurface oiling (probability >40 %) include:

- Mousa to Boddam NC MPA (55 %).
- Turbot Bank NC MPA (97 %).

Conclusion

In summary, the protected features / qualifying species from 53 MPAs (33 x SPA; 9 x SAC; 5 x RAMSAR; 5 x NC MPA; 1 x MCZ) are at **Medium** risk from a large-scale oiling event which could adversely impact their conservation objectives. This reflects high potential consequences for sensitive receptors (i.e. 'Medium' to 'Very High' sensitivity) if exposure were to occur, tempered by the Extremely Rare likelihood of a well blowout. The majority of these MPAs are designated for the protection of seabirds, which, as previously discussed, are particularly sensitive to oil contamination.

All other designated sites at risk from oiling but not listed in Table 11.13 are considered to be at **Low** risk, either because predicted severities are low or because there is no credible exposure pathway (e.g. sites designated for benthic or seabed features).

Uncertainty has been addressed through the use of worst case spill parameters and precautionary thresholds (>0.3 µm for surface oiling; 1–10 litres/m² for shoreline oiling; 70.5 ppb THC for water-column exposure). Seasonal and hydrodynamic variability are captured within the stochastic modelling. On this basis, while localised adverse effects could occur at the most exposed MPAs designated for seabirds, marine mammals or fish under the worst case scenario, persistent or large-scale impacts across the MPA network are not expected.

Detailed site-specific probabilities, minimum arrival times, and predicted severities are presented in Appendix F (Section F.3.3) and underpin the effect evaluations provided in Table 11.13.

Table 11.13: Assessment of MPAs with Qualifying Features at Risk from Oiling

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Special Protected Areas (SPA) with Marine Components										
Auskerry SPA	14 %	BAOAC 3	N/A	N/A	24 %	Below OSPAR PNEC	**Qualifying Species:** Arctic tern (*Sterna paradisaea*), European storm-petrel (*Hydrobates pelagicus*). **Assemblage:** a diverse overall assemblage of breeding seabirds (14 species).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Bluemull and Colgrave Sounds SPA	8 %	BAOAC 3	3 %	Light Oiling	18 %	Below OSPAR PNEC	**Qualifying Species:** Red-throated diver Gavia stellate (breeding).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Buchan Ness to Collieston Coast SPA	68 %	BAOAC 3	39 %	Moderate Oiling	61 %	Above OSPAR PNEC	**Qualifying Species:** Black-legged kittiwake (*Rissa tridactyla*), Common guillemot (*Uria aalge*), European shag (*Phalacrocorax aristotelis*), Northern fulmar (*Fulmarus glacialis*), Herring gull (*Larus argentatus*). **Assemblage:** Seabird breeding assemblage.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Calf of Eday SPA	2 %	BAOAC 3	1 %	Light Oiling	19 %	Below OSPAR PNEC	**Qualifying Species**: (breeding) Arctic tern (*Sterna paradisaea*); Arctic skua (*Stercorarius parasiticus*); Great black-backed gull (*Larus marinus*); Herring gull (*Larus argentatus*); Common guillemot (*Uria aalge*); Razorbill (*Alca torda*). **Assemblage:** Seabird breeding assemblage — regularly supports >20,000 individual seabirds.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Copinsay SPA	33 %	BAOAC 3	6 %	Light Oiling	43 %	Below OSPAR PNEC	**Qualifying Species:** (breeding) Northern fulmar (*Fulmarus glacialis*), European shag (*Phalacrocorax aristotelis*), black-legged kittiwake (*Rissa tridactyla*), common guillemot (*Uria aalge*), razorbill (*Alca torda*). **Assemblage:** Seabird breeding assemblage — regularly supports over 90,000 individual seabirds.	Very High	Major	Major x Extremely Rare = **MEDIUM**
East Caithness Cliffs SPA	10 %	BAOAC 3	3 %	Light Oiling	10 %	Below OSPAR PNEC	**Qualifying Species:** Qualifying Species (breeding): Peregrine falcon (*Falco peregrinus*), common guillemot (*Uria aalge*), razorbill (*Alca torda*), herring gull (*Larus argentatus*), black-legged kittiwake (*Rissa tridactyla*), European shag (*Phalacrocorax aristotelis*), great black-backed gull (*Larus marinus*), northern fulmar (*Fulmarus glacialis*). **Assemblage:** Seabird breeding assemblage (>100,000 individual seabirds).	Very High	Major	Major x Extremely Rare = **MEDIUM**
East Mainland Coast Shetland SPA	12 %	BAOAC 3	8 %	Light Oiling	30 %	Above OSPAR PNEC	**Qualifying Species:** (breeding) Red-throated diver (*Gavia stellata*); Arctic tern (*Sterna paradisaea*); Black-legged kittiwake (*Rissa tridactyla*); Common guillemot (*Uria aalge*); Northern fulmar (*Fulmarus glacialis*); Atlantic puffin (*Fratercula arctica*). **Assemblage:** Breeding seabird assemblage (>50,000 individuals).	Very High	Major	Major x Extremely Rare = **MEDIUM**
East Sanday Coast SPA	5 %	BAOAC 3	2 %	Light Oiling	N/A	N/A	**Qualifying Species:** Arctic tern (*Sterna paradisaea*), breeding; Red-throated diver (*Gavia stellata*), breeding; Purple sandpiper (*Calidris maritima*), non-breeding; Turnstone (*Arenaria interpres*), non-breeding. **Assemblage:** Non-breeding wader assemblage >20,000 individuals.	Very High	Major	Major x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Fair Isle SPA	48 %	BAOAC 3	12 %	Light Oiling	71 %	Above OSPAR PNEC	**Qualifying Species:** (breeding) Arctic tern (*Sterna paradisaea*), northern fulmar (*Fulmarus glacialis*), European shag (*Phalacrocorax aristotelis*), common guillemot (*Uria aalge*), Atlantic puffin (*Fratercula arctica*). **Assemblage:** Seabird breeding assemblage — over 170,000 individual seabirds.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Fetlar SPA	15 %	BAOAC 3	4 %	Light Oiling	N/A	N/A	**Qualifying Species:** (breeding) Arctic tern (*Sterna paradisaea*), red-throated diver (*Gavia stellata*), Arctic skua (*Stercorarius parasiticus*). **Assemblage:** Seabird breeding assemblage (>20,000 individuals) — includes fulmar, puffin, kittiwake, guillemot.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Firth of Forth SPA	27 %	BAOAC 3	10 %	Light Oiling	51 %	Above OSPAR PNEC	**Qualifying Species:** (breeding) Common tern (*Sterna hirundo*), Arctic tern (*Sterna paradisaea*), roseate tern (*Sterna dougallii*), sandwich tern (*Thalasseus sandvicensis*), cormorant (*Phalacrocorax carbo*), shag (*Phalacrocorax aristotelis*), gannet (*Morus bassanus*), kittiwake (*Rissa tridactyla*). **Assemblage:** Seabird breeding assemblage (>20,000 individuals); intertidal habitats support large non-breeding waterbird assemblage (>100,000 individuals).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Forth Islands SPA	49 %	BAOAC 3	33 %	Moderate Oiling	67 %	Above OSPAR PNEC	**Qualifying Species:** (breeding) Northern gannet (*Morus bassanus*), Atlantic puffin (*Fratercula arctica*), common guillemot (*Uria aalge*), razorbill (*Alca torda*), black-legged kittiwake (*Rissa tridactyla*), sandwich tern (*Thalasseus sandvicensis*), Arctic tern (*Sterna paradisaea*). **Assemblage:** Seabird breeding assemblage (>90,000 seabirds).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Fowlsheugh SPA	61 %	BAOAC 3	18 %	Moderate Oiling	57 %	Above OSPAR PNEC	**Qualifying Species:** Black-legged kittiwake (*Rissa tridactyla*), Common guillemot (*Uria aalge*), Herring gull (*Larus argentatus*), Northern fulmar (*Fulmarus glacialis*), Razorbill (*Alca torda*). **Assemblage:** Seabird breeding assemblage (>20,000 individuals).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Hermaness, Saxa Vord and Valla Field SPA	3 %	BAOAC 2	1 %	Light Oiling	18 %	Below OSPAR PNEC	**Qualifying Species:** Northern gannet (*Morus bassanus*), Northern fulmar (*Fulmarus glacialis*), European shag (*Phalacrocorax aristotelis*), Black-legged kittiwake *(Rissa tridactyla*), Common guillemot (*Uria aalge*), Atlantic puffin (*Fratercula arctica*), Great skua (*Stercorarius skua*), Red-throated diver (*Gavia stellata*). **Assemblage:** During the breeding season the area regularly supports 152,000 individual seabirds.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Hoy SPA	10 %	BAOAC 3	1 %	Light Oiling	16 %	Below OSPAR PNEC	**Qualifying Species:** red-throated diver (*Gavia stellata*), breeding; peregrine falcon (*Falco peregrinus*), breeding; great skua (Stercorarius skua), breeding. **Assemblage:** Regularly supports >20,000 individual seabirds including Atlantic puffin (*Fratercula arctica*), black-legged kittiwake (*Rissa tridactyla*), Arctic skua (*Stercorarius parasitus*) and others.	Very High	Major	Major x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Humber Estuary SPA	1 %	BAOAC 3	N/A	N/A	1 %	Below OSPAR PNEC	**Qualifying Species:** avocet (*Recurvirostra avosetta*); bar-tailed godwit (*Limosa lapponica*); bittern (*Botaurus stellaris*); black-tailed godwit (*Limosa limosa*); dunlin (*Calidris alpina*); golden plover (*Pluvialis apricaria*); hen harrier (*Circus cyaneus*); knot (*Calidris canutus*); little tern (*Sternula albifrons*); marsh harrier (*Circus aeruginosus*); redshank (*Tringa totanus*); ruff (*Philomachus pugnax*); shelduck (*Tadorna tadorna*), as well as waterbird assemblage.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Loch of Strathbeg SPA	N/A	N/A	8 %	Moderate Oiling	N/A	N/A	**Qualifying Species:** sandwich tern (*Sterna sandvicensis*), breeding; whooper swan (*Cygnus cygnus*), wintering; Svalbard barnacle goose (*Branta leucopsis*), wintering; pink-footed goose (*Anser brachyrhynchus*), wintering; greylag goose (*Anser anser*), wintering; teal (*Anas crecca*), wintering; goldeneye (*Bucephala clangula*), wintering. **Assemblage:** Winter waterbird assemblage >20,000 individuals.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Moray Firth SPA	14 %	BAOAC 3	5 %	Light Oiling	18 %	Below OSPAR PNEC	**Qualifying Species:** (non-breeding unless stated) Great northern diver (*Gavia immer*); Red-throated diver (*Gavia stellata*); Slavonian grebe (*Podiceps auritus*). Qualifying migratory waterbirds: Greater scaup (*Aythya marila*); Common eider (*Somateria mollissima*); Long-tailed duck (*Clangula hyemalis*); Common scoter (*Melanitta nigra*); Velvet scoter (*Melanitta fusca*); Goldeneye (*Bucephala clangula*); Red-breasted merganser (*Mergus serrator*); European shag (*Phalacrocorax aristotelis*).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Mousa SPA	N/A	N/A	8 %	Light Oiling	50 %	Above OSPAR PNEC	**Qualifying Species:** European storm-petrel (*Hydrobates pelagicus*), breeding; Arctic tern (*Sterna paradisaea*), breeding.	Very High	Major	Major x Extremely Rare = **MEDIUM**
North Caithness Cliffs SPA	14 %	BAOAC 3	2 %	Light Oiling	17 %	Below OSPAR PNEC	**Qualifying Species:** (breeding) Peregrine falcon (*Falco peregrinus*), black-legged kittiwake (*Rissa tridactyla*), northern fulmar (*Fulmarus glacialis*), common guillemot (*Uria aalge*), razorbill (*Alca torda*), Atlantic puffin (*Fratercula arctica*). **Assemblage:** Seabird breeding assemblage (~ 130,000 seabirds).	Very High	Major	Major x Extremely Rare = **MEDIUM**
North Orkney SPA	8 %	BAOAC 3	2 %	Light Oiling	16 %	Below OSPAR PNEC	**Qualifying Species:** Great northern diver (*Gavia immer*), non-breeding; Slavonian grebe (*Podiceps auritus*), non-breeding; Velvet scoter (*Melanitta fusca*), non-breeding; Red-throated diver (*Gavia stellata*), breeding.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Northumberland Marine SPA	29 %	BAOAC 3	N/A	N/A	59 %	Above OSPAR PNEC	**Qualifying Species:** (foraging) Arctic tern (*Sterna paradisaea*), common tern (*Sterna hirundo*), roseate tern (*Sterna dougallii*), sandwich tern (*Thalasseus sandvicensis*), little tern (*Sternula albifrons*). **Assemblage:** Marine foraging area supporting >20,000 individual breeding terns from nearby colonies (Coquet Island, Farne Islands, Lindisfarne).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Noss SPA	17 %	BAOAC 3	6 %	Light Oiling	32 %	Above OSPAR PNEC	**Qualifying Species:** (breeding) Northern gannet (*Morus bassanus*); Black-legged kittiwake (*Rissa tridactyla*); Common guillemot (*Uria aalge*); Northern fulmar (*Fulmarus glacialis*); Atlantic puffin (*Fratercula arctica*); Great skua (*Stercorarius skua*); European shag (*Phalacrocorax aristotelis*). **Assemblage:** Seabird breeding assemblage — regularly supports >140,000 individual seabirds.	Very High	Major	Major x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Outer Firth of Forth and St Andrews Bay Complex SPA	59 %	BAOAC 3	33 %	Moderate Oiling	68 %	Above OSPAR PNEC	**Qualifying Species**: Sandwich tern (*Sterna sandvicensis*), Arctic tern (*Sterna paradisaea*), roseate tern (*Sterna dougallii*), common tern (*Sterna hirundo*) — breeding; Breeding seabird assemblage including kittiwake (*Rissa tridactyla*), shag (*Phalacrocorax aristotelis*), cormorant (*Phalacrocorax carbo*), Atlantic puffin (*Fratercula arctica*), common guillemot (*Uria aalge*).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Papa Stour SPA	2 %	BAOAC 3	1 %	Light Oiling	N/A	N/A	**Qualifying Species:** Arctic tern (*Sterna paradisaea*), breeding; ringed plover (*Charadrius hiaticula*), breeding (migratory species).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Rousay SPA	5 %	BAOAC 3	1 %	Light Oiling	N/A	N/A	**Qualifying Species:** Arctic tern (*Sterna paradisaea*), breeding. Assemblage: supports ~30,000 individual seabirds including guillemot (*Uria aalge*), kittiwake (Rissa tridactyla), Arctic skua (*Stercorarius parasitus*), fulmar (*Fulmarus glacialis*).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Scapa Flow SPA	25 %	BAOAC 3	N/A	N/A	35 %	Above OSPAR PNEC	**Qualifying Species:** (non-breeding) Great northern diver (*Gavia immer*), Slavonian grebe (*Podiceps auritus*), long-tailed duck (*Clangula hyemalis*), common eider (*Somateria mollissima*), common goldeneye (*Bucephala clangula*), red-breasted merganser (*Mergus serrator*). **Assemblage:** Non-breeding waterfowl assemblage (>20,000 individuals) supported by sheltered bays and shallow inshore waters.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Seas Off Foula SPA	36 %	BAOAC 3	N/A	N/A	70 %	Above OSPAR PNEC	**Qualifying Species:** Arctic skua (*Stercorarius parasiticus*), Arctic tern (*Sterna paradisaea*), black-legged kittiwake (*Rissa tridactyla*), common guillemot (*Uria aalge*), great skua (*Stercorarius skua*). **Assemblage:** Offshore extension designated to protect foraging habitat for breeding seabird assemblages of Foula SPA.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Sumburgh Head SPA	41 %	BAOAC 3	12 %	Moderate Oiling	70 %	Above OSPAR PNEC	**Qualifying Species:** includes large breeding seabird colony counts—kittiwake, guillemot, razorbill. **Assemblage:** internationally important seabird breeding assemblage.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Teesmouth and Cleveland Coast SPA	3 %	BAOAC 3	1 %	Light Oiling	33 %	Below OSPAR PNEC	**Qualifying Species:** Little tern (*Sternula albifrons*), breeding; Sandwich tern (*Thalasseus sandvicensis*), passage; Common tern (*Sterna hirundo*), breeding; Avocet (*Recurvirostra avosetta*), breeding; Winter water-bird assemblage (>20,000 individuals) including Red knot (*Calidris canutus*), Common redshank (*Tringa totanus*).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Troup, Pennan and Lion's Heads SPA	23 %	BAOAC 3	7 %	Light Oiling	19 %	Below OSPAR PNEC	**Qualifying Species:** (breeding) Common guillemot (*Uria aalge*); Razorbill (*Alca torda*); Black-legged kittiwake (*Rissa tridactyla*); Northern fulmar (*Fulmarus glacialis*); Herring gull (*Larus argentatus*). **Assemblage:** Seabird breeding assemblage (~150,000 seabirds).	Very High	Major	Major x Extremely Rare = **MEDIUM**
West Westray SPA	3 %	BAOAC 3	2 %	Light Oiling	18 %	Below OSPAR PNEC	**Qualifying Species:** Arctic tern (*Sterna paradisaea*), breeding; common guillemot (*Uria aalge*), breeding. **Assemblage:** regularly supports ~120,000 individual seabirds including razorbill (*Alca torda*), kittiwake (*Rissa tridactyla*), Arctic skua (*Stercorarius parasitus*), fulmar (*Fulmarus glacialis*).	Very High	Major	Major x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Ythan Estuary, Sands of Forvie and Meikle Loch SPA	64 %	BAOAC 3	39 %	Moderate Oiling	61 %	Above OSPAR PNEC	**Qualifying Species:** sandwich tern (*Sterna sandvicensis*), breeding; common tern (*Sterna hirundo*), breeding; little tern (*Sternula albifrons*), breeding; pink-footed goose (*Anser brachyrhynchus*), wintering; eider (*Somateria mollissima*), wintering. **Assemblage:** Winter waterfowl assemblage >20,000 individuals.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Special Area of Conservation (SAC) with Marine Components										
Berwickshire and North Northumberland Coast SAC	30 %	BAOAC 3	10 %	Moderate Oiling	58 %	Above OSPAR PNEC	**Annex I Habitats:** Reefs; Large shallow inlets and bays; Subtidal sandbanks slightly covered by seawater all the time. **Annex II Species:** Grey seal (*Halichoerus grypus*). Notes: The site contains extensive subtidal reefs, kelp forest communities, and haul-out areas for breeding grey seals at the Farne Islands.	High	Major	Major x Extremely Rare = **MEDIUM**
Faray and Holm of Faray SAC	2 %	BAOAC 3	N/A	N/A	17 %	Below OSPAR PNEC	**Annex II Species:** Grey seal (*Halichoerus grypus*). Notes: One of the most important grey seal breeding colonies in the UK; supports ~4 % of the annual UK pup production.	High	Major	Major x Extremely Rare = **MEDIUM**
Firth of Tay and Eden Estuary SAC	54 %	BAOAC 3	17 %	Moderate Oiling	54 %	Below OSPAR PNEC	**Annex I Habitats:** Mudflats and sandflats not covered by seawater at low tide; Estuaries; Subtidal sandbanks slightly covered by seawater all the time. **Annex II Species:** Harbour seal (*Phoca vitulina*), Common (river) lamprey (*Lampetra fluviatilis*), Sea lamprey (*Petromyzon marinus*), Atlantic salmon (*Salmo salar*). Notes: Complex estuarine system supporting large populations of seals and migratory fish.	High	Major	Major x Extremely Rare = **MEDIUM**
Humber Estuary SAC	1 %	BAOAC 3	N/A	N/A	1 %	Below OSPAR PNEC	**Annex I Habitats:** Estuaries; Mudflats and sandflats not covered by seawater at low tide; Sandbanks slightly covered by seawater all the time; Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*); Salicornia and other annuals colonising mud and sand. **Annex II Species:** Sea lamprey (*Petromyzon marinus*), River lamprey (*Lampetra fluviatilis*), Grey seal (*Halichoerus grypus*)	High	Major	Major x Extremely Rare = **MEDIUM**
Mousa SAC	N/A	N/A	24 %	Moderate Oiling	51 %	Above OSPAR PNEC	**Annex I Habitats:** Reefs; Subtidal sandbanks slightly covered by seawater all the time. **Annex II Species:** Grey seal (*Halichoerus grypus*). Notes: Mousa Sound and surrounding reefs provide important pupping habitat and foraging grounds for grey seals.	High	Major	Major x Extremely Rare = **MEDIUM**
River Dee SAC	24 %	BAOAC 3	N/A	N/A	7 %	Below OSPAR PNEC	**Annex I Habitats:** None marine-specific (fluvial site). **Annex II Species:** Atlantic salmon (*Salmo salar*), Freshwater pearl mussel (*Margaritifera margaritifera*), Otter (*Lutra lutra*). Notes: Although primarily a freshwater site, the lower Dee includes a short estuarine section with transitional habitat; Atlantic salmon and otter provide marine connectivity.	High	Major	Major x Extremely Rare = **MEDIUM**
Sanday SAC	8 %	BAOAC 3	3 %	Light Oiling	19 %	Below OSPAR PNEC	**Annex I Habitats:** Sandbanks slightly covered by seawater all the time; Mudflats and sandflats not covered by seawater at low tide; Large shallow inlets and bays; Reefs; Submerged or partially submerged sea caves. **Annex II Species:** Harbour seal (*Phoca vitulina*). Notes: Extensive shallow marine and intertidal habitats supporting nationally important harbour-seal populations and diverse benthic communities.	High	Major	Major x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Sullom Voe SAC	1 %	BAOAC 3	N/A	N/A	12 %	Below OSPAR PNEC	**Annex I Habitats:** Large shallow inlets and bays; Mudflats and sandflats not covered by seawater at low tide; Sandbanks slightly covered by seawater all the time; Reefs. **Annex II Species:** Common (harbour) seal (*Phoca vitulina*). Notes: Deep, sheltered inlet with extensive shallow-water reef and sandbank habitats; supports one of the largest Shetland harbour-seal colonies.	High	Major	Major x Extremely Rare = **MEDIUM**
Yell Sound Coast SAC	4 %	BAOAC 3	2 %	Light Oiling	19 %	Below OSPAR PNEC	**Annex I Habitats:** Reefs; Subtidal sandbanks slightly covered by seawater all the time. **Annex II Species:** Otter (*Lutra lutra*). Notes: The site's complex coastline provides ideal marine foraging and holt habitat for otters; also includes high-diversity kelp-covered reef systems.	High	Major	Major x Extremely Rare = **MEDIUM**
RAMSAR										
East Sanday Coast RAMSAR	5 %	BAOAC 3	2 %	Light Oiling	18 %	Below OSPAR PNEC	**Ramsar Criteria:** 1, 2, 5, 6. **Qualifying Features:** Extensive intertidal sand and mudflats, reefs, and dune systems supporting internationally important populations of wintering waders and wildfowl, including purple sandpiper (*Calidris maritima*) and ruddy turnstone (*Arenaria interpres*). Also supports breeding populations of Arctic tern (*Sterna paradisaea*) and red-throated diver (*Gavia stellata*). Notes: Represents one of the best examples in the UK of island coastal systems supporting rich intertidal invertebrate communities.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Firth of Forth RAMSAR	N/A	N/A	13 %	Moderate Oiling	N/A	N/A	**Ramsar Criteria:** 1, 5, 6. **Qualifying Features:** Intertidal mudflats, sandflats, and saltmarshes supporting internationally important numbers of wintering and passage waterbirds (including bar-tailed godwit *Limosa lapponica*, red knot *Calidris canutus*, and pink-footed goose *Anser brachyrhynchus*). **Assemblage:** Over 100,000 individual waterbirds regularly supported. Notes: One of the most extensive estuarine complexes on the east coast of Britain.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Firth of Tay and Eden Estuary RAMSAR	N/A	N/A	17 %	Moderate Oiling	N/A	N/A	**Ramsar Criteria:** 1, 2, 5, 6. **Qualifying Features:** Extensive estuarine complex of mudflats, sandbanks, and saltmarsh; supports important populations of wintering and passage waterbirds including shelduck (*Tadorna tadorna*), redshank (*Tringa totanus*), and eider (*Somateria mollissima*). Species of note: Harbour seal (*Phoca vitulina*), common and sea lamprey, and Atlantic salmon (*Salmo salar*). **Assemblage:** >20,000 waterbirds regularly supported.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Humber Estuary RAMSAR	1 %	BAOAC 3	N/A	N/A	1 %	Below OSPAR PNEC	**Ramsar Criteria:** 1, 2, 5, 6. **Qualifying Features:** Extensive intertidal mudflats, sandflats, and saltmarshes; breeding and wintering populations of internationally important waterbirds such as knot (*Calidris canutus*), dunlin (*Calidris alpina*), redshank (*Tringa totanus*), shelduck (*Tadorna tadorna*), and avocet (*Recurvirostra avosetta*). **Assemblage:** >140,000 waterbirds. Additional Interests: Supports significant grey and harbour seal populations and important fish nursery grounds.	Very High	Major	Major x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Loch of Strathbeg RAMSAR	N/A	N/A	8 %	Moderate Oiling	N/A	N/A	**Ramsar Criteria:** 1, 2, 5, 6. **Qualifying Features:** Large coastal freshwater loch and associated reedbeds supporting internationally important wintering populations of whooper swan (*Cygnus cygnus*), pink-footed goose (*Anser brachyrhynchus*), and greylag goose (*Anser anser*). **Assemblage:** >20,000 individual waterbirds regularly supported. Notes: Also, of national importance for breeding and migratory terns.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Nature Conservation Marine Protected Areas (NC MPA)										
East Caithness Cliffs NC MPA	10 %	BAOAC 3	3 %	Light Oiling	10 %	Below OSPAR PNEC	**Protected Features:** Seabird aggregations (black-legged kittiwake *Rissa tridactyla*, guillemot *Uria aalge*, razorbill *Alca torda*, fulmar *Fulmarus glacialis*). **Feature Type:** Biodiversity. **Description:** Supports high-density breeding and foraging seabird populations associated with adjacent SPA cliff colonies. Offshore waters provide key feeding habitat linking several SPAs (e.g. Troup, Pennan and Lion's Heads; North Caithness Cliffs).	Very High	Major	Major x Extremely Rare = **MEDIUM**
Fetlar to Haroldswick NC MPA	15 %	BAOAC 3	4 %	Light Oiling	19 %	Above OSPAR PNEC	**Protected Features:** Black guillemot (*Cepphus grylle*); circalittoral sand and coarse sediment communities; horse mussel beds; kelp and seaweed communities on sublittoral sediments; maerl beds; shallow tide-swept coarse sands with burrowing bivalves. **Feature Type:** Biodiversity (habitats & seabird). **Description:** This high-energy marine area between Fetlar, Unst, Yell and Haroldswick supports rich biodiversity including extensive maerl beds, horse mussel beds, kelp forests and tide-swept sandy sediments, as well as a nationally important population of black guillemots. Designated to conserve these features and the seabed ecosystems which underpin seabird foraging and benthic productivity	Very High	Major	Major x Extremely Rare = **MEDIUM**
Mousa to Boddam NC MPA	24 %	BAOAC 3	N/A	N/A	55 %	Above OSPAR PNEC	**Protected Features:** Sandeels (*Ammodytes marinus*). **Feature Type:** Biodiversity (fish species). **Description:** Extensive sandy and gravelly sediments in this area support one of the most important sandeel grounds in the North Sea, feeding seabirds from the Mousa, Noss, and Hermaness SPAs. Designated to protect spawning and nursery habitat.	Medium	Major	Moderate x Extremely Rare = **MEDIUM**

Protected Area	Surface Oil		Shoreline Oil		Subsurface Oil		Protected Features / Qualifying Species at Risk from Oiling	Impact Assessment [Note 1]		
	Probability	Maximum Severity	Probability	Maximum Severity	Probability	Maximum Severity		Sensitivity to Oiling	Magnitude of Oiling Impact	Significance Evaluation (Consequence x Likelihood)
Papa Westray NC MPA	2 %	BAOAC 3	1 %	Light Oiling	16 %	Below OSPAR PNEC	**Protected Features:** Black guillemot (*Cepphus grylle*). **Feature Type:** Biodiversity (seabird). **Description:** Coastal waters surrounding Papa Westray provide vital breeding, roosting, and foraging areas for black guillemots, particularly during the post-breeding and wintering periods. The site supports one of the most significant populations of this species in Orkney.	Very High	Major	Major x Extremely Rare = **MEDIUM**
Turbot Bank NC MPA	99 %	BAOAC 3	N/A	N/A	97 %	Above OSPAR PNEC	**Protected Features:** Sandeels (*Ammodytes marinus*). **Feature Type:** Biodiversity (fish species). **Description:** Large offshore sandbank (40–70 m depth) supporting dense sandeel populations that are key prey for seabirds, marine mammals, and demersal fish. Represents one of the few extensive offshore sand habitats of this type in the UK sector.	Medium	Major	Moderate x Extremely Rare = **MEDIUM**
Marine Conservation Zones (MCZ)										
Berwick to St Mary's MCZ	30 %	BAOAC 3	7 %	Light Oiling	55 %	Below OSPAR PNEC	**Protected Feature (Species):** Common eider (*Somateria mollissima*). **Supporting Habitats:** Intertidal coarse, mixed and mud sediments; intertidal and subtidal rock; subtidal sand and mixed sediments — providing essential foraging and loafing areas for eider. **Feature Type:** Species (sea duck). **Description:** Designated to protect the key breeding and non-breeding population of common eider along the Northumberland coast between Berwick-upon-Tweed and St Mary's Island. The MCZ encompasses extensive rocky and sedimentary shore habitats used for feeding, preening and displaying, supporting one of England's most important eider populations.	Very High	Major	Major x Extremely Rare = **MEDIUM**

11.4.9 Socio-economic Receptors

Commercial Fisheries

Major oil spills can have a serious impact on commercial fishing activities through physical contamination of fish, oiling of fishing boats and gear and loss of access to fishing grounds as well as market confidence (ITOPF, 2014c).

Commercial fishing activity within the Kyla Development area (ICES Rectangle 42F1) is low to moderate in intensity, characterised primarily by *Nephrops norvegicus* (Norway lobster) trawl fisheries. Over the 2019–2023 period, shellfish landings dominated both by weight (70 %) and by value (87 %), followed by demersal species such as haddock, whiting and monkfish, which together account for nearly one-third of the total live weight. Pelagic species (e.g. herring and mackerel) contributed less than 1 % of the overall catch. The average annual landings from ICES Rectangle 42F1 were approximately 393 tonnes, with an annual value of around £1.13 million (SG-MD, 2025). The local fishery therefore comprises a mixed *Nephrops* and whitefish trawl fishery, supported by small-scale shellfish activity. Overall, fishing effort and landings indicate that the Kyla development area supports a minor but regionally consistent component of the broader CNS fishery, with economic value largely dependent on *Nephrops* landings (refer to Section 4.4.1).

Modelling predicts that water-column oiling at concentrations exceeding 10 ppb, the level at which fish tainting may occur, could extend up to 1,329 km from the Kyla release location (refer to Figure 11.9). Elevated subsurface oiling concentrations (>OSPAR PNEC 70.5 ppb) are predicted across wide areas of the CNS, extending eastwards and south-eastwards into the Norwegian Trench and Skagerrak region, particularly during autumn and winter (refer to Figure 11.4). Although fish mortality is unlikely to occur at these concentrations, toxicological and sub-lethal effects such as impaired feeding or reproduction may arise (ITOPF, 2014b). The maximum area at risk of exposure above 70.5 ppb is approximately 154,651 km² during autumn. Vertical-profile modelling indicates that elevated concentrations remain largely within the upper water column, with limited downward penetration due to droplet buoyancy; thus, pelagic fish stocks are at greatest risk under the worst-case blowout scenario.

Throughout the spill duration, surface oiling could temporarily displace fishing vessels from the affected region. Modelling indicates that the oil slick could cover an area of 6,772 – 21,840 km² at any one time; however, the slick is short-lived, with minimal surface oil (0.02 – 0.68 % of the total release volume) remaining 10 days after cessation of the blowout.

In summary, the sensitivity of commercial fisheries to a blowout is considered to be **High**. The receptor has a Very High value as the Kyla Development area and wider CNS region are fished by both UK and international fleets. However, receptor resistance and resilience is High as the oil is not predicted to persist and fishing vessels may be able to temporarily switch to alternative fishing grounds. The magnitude of impact is considered to be **Major**, reflecting the large CNS area subject to elevated water-column concentrations (>70.5 ppb), although rapid recovery to baseline conditions is expected within 10 days after release cessation. Effects on commercial fisheries due to the blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to commercial fisheries from a well blowout is considered to be **Medium**.

Aquaculture

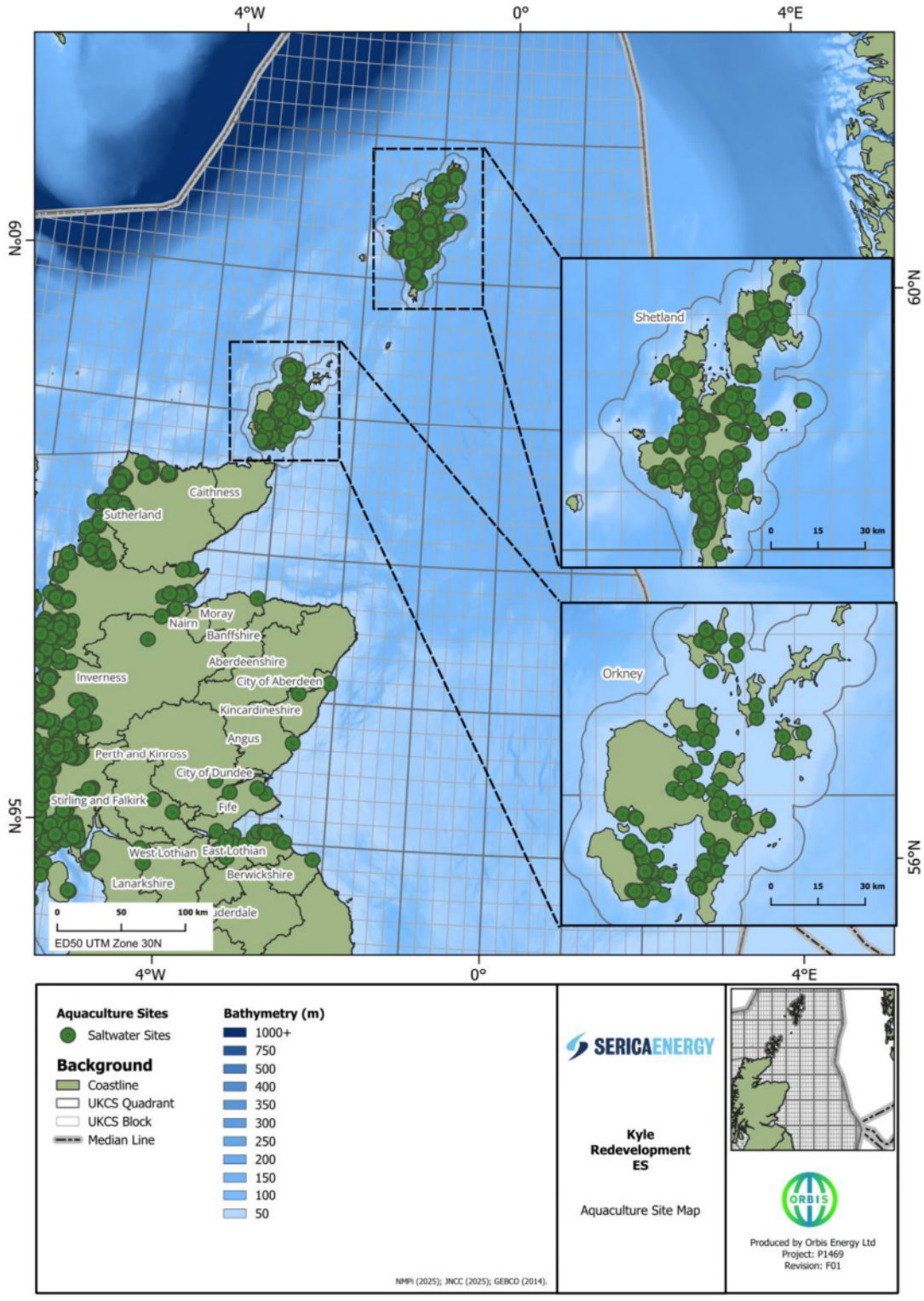
Aquaculture is a major industry in Scottish coastal waters, with the highest concentration of marine sites located around the Shetland Islands, Orkney Islands, and along the north and west coasts of mainland Scotland (refer to Figure 11.11). The sector is dominated by Atlantic salmon (*Salmo salar*) production within sea cages, with additional cultivation of mussels (*Mytilus edulis*), Pacific oysters (*Crassostrea gigas*), and other shellfish species (Marine Scotland, 2020; Scottish Government, 2023; HIE, 2017). No aquaculture sites are located in the vicinity of the Kyla Development area or elsewhere within the CNS (refer to Section 4.4.2).

Aquaculture operations are inherently vulnerable to hydrocarbon pollution, as caged fish and shellfish are unable to avoid exposure, and bioaccumulation or tainting can occur even at relatively low concentrations of dissolved hydrocarbons. Stochastic modelling indicates that subsurface oiling at higher concentrations (>OSPAR PNEC 70.5 ppb) will remain predominantly offshore in the CNS and extend eastwards and south-eastwards into the Norwegian Trench and Skagerrak region (Figure 11.4). These elevated concentrations are transient and are mainly confined to the upper water column, where they dissipate rapidly through dilution and biodegradation following cessation of the blowout release.

However, model results also predict that fish-tainting concentrations (>10 ppb) could extend towards the northern Scottish coast (Figure 11.9), particularly around Shetland and Orkney, where aquaculture sites are concentrated Even minor contamination leading to fish tainting can have severe economic and reputational consequences for the sector, as products entering the human food chain are subject to strict quality assurance and safety standards (ITOPF, 2014d; FAO, 2018). In addition, areas of moderate shoreline oiling (1–10 litres/m²) are predicted along discrete stretches of the north-east mainland and Shetland coastline (refer to Figure 11.7), indicating potential risk of surface residue contamination to nearshore infrastructure. While these exposures are expected to be short-lived and spatially limited, localised tainting or fouling of aquaculture cages and infrastructure could occur if operations coincide with peak subsurface or surface oil concentrations.

In summary, the sensitivity of aquaculture to a blowout is considered to be **High**. The receptor has a Medium value; the aquaculture is of regional importance. Aquaculture sites are vulnerable to oiling exposure as the farmed fish / shellfish are unable to avoid or more away from oil pollution; therefore, the receptor resistance and resilience is Low to oil pollution. The magnitude of impact is considered to be **Major**, as the worst case oil spill modelling revealed that inshore areas of north east Scotland, particularly around Shetland and Orkney may be exposed to fish-tainting concentrations (>10 ppb). Effects on aquaculture due to the blowout scenario are therefore assessed as **Major**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to aquaculture from a well blowout is considered to be **Medium**.

Figure 11.11: Active Aquaculture Sites around Scotland



Recreational Activity and Tourism

In coastal areas, oil spills can result in economic losses to tourism and recreation through shoreline contamination, aesthetic degradation, and access restrictions, as well as the costs associated with clean-up operations (ITOPF, 2014c). Even light surface residues or odours can deter visitors and affect public perception of environmental quality.

Within the wider model domain, tourism and recreational activity are concentrated along the Shetland and Orkney coastlines, and the north-east mainland of Scotland, where activities include wildlife watching, sea angling, sailing, kayaking, and shore-based recreation. Coastal ecotourism in Shetland and Orkney is particularly centred around seabird colonies, seals, and cetacean watching, while recreational diving occurs in sheltered areas with rocky reefs and kelp beds that support diverse marine life (VisitScotland, 2023; Marine Scotland, 2020).

Model results predict that shoreline oiling probabilities are highest along the north-east mainland coast (up to 39 %), with lower probabilities around Shetland (12 %) and Orkney (8 %) (refer to Figure 11.7 and Table 11.6). Predicted shoreline oiling is of low to moderate severity (up to 10 litres/m²) and is not expected to persist beyond the short term. Ten days after cessation of the blowout release, the majority of oil is predicted to have dispersed or degraded through natural weathering and tidal processes. Consequently, while temporary visual or odour effects could occur in isolated coastal areas, widespread or long-term disruption to tourism and recreational activity is unlikely.

In summary, the sensitivity of recreational activity and tourism to a blowout is considered to be **Medium**. The receptor has a High value; recreational activity and tourism is of importance to the local economy. However, the oil does not persist with recreational activity and tourism expected to recovery in the short to medium term; therefore, the receptor resistance and resilience is High to oil pollution. The magnitude of impact is considered to be **Moderate**, as shoreline oiling at all locations is predicted to be of low to moderate severity, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after the blowout cessation. Effects on recreational activity and tourism due to the blowout scenario are therefore assessed as **Minor**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to recreational activity and tourism from a well blowout is considered to be **Low**.

11.5 Potential for a Major Environmental Incident

A MEI is defined as "*an incident which results, or is likely to result, in significant adverse effects on the environment in accordance with Directive 2004/35/EC of the European Parliament and the of the Council on environmental liability with regard to the prevention and remedying of environmental damage*".

Under Directive 2004/35/EC, "*environmental damage*" is defined as:

- *"Damage to protected species and natural habitats, which is any damage that has significant adverse effects on reaching or maintaining the favourable conservation status of such habitats or species. The significance of such effects is to be assessed with reference to the baseline condition, taking account of the criteria set out in Annex I";*
- *"Water damage, which is any damage that significantly adversely affects the ecological, chemical and/or quantitative status and/or ecological potential, as defined in Directive 2000/60/EC, of the waters concerned, with the exception of adverse effects where Article 4(7) of that Directive applies";*
- *"Land damage, which is any land contamination that creates a significant risk of human health being adversely affected as a result of the direct or indirect introduction, in, on or under land, of substances, preparations, organisms or micro-organisms".*

For an event to be considered as a MEI, a major accident (as defined under SCR 2015) must be a precursor (BEIS, 2017). For the proposed Kyla Development, the major accident scenario that would result in the largest release of hydrocarbons is:

- Loss of well control and subsequent blowout that can only be stopped by drilling a relief well.

Based on the results of the oil spill modelling (Section 11.3.2 and Appendix F) and the assessment of environmental and socio-economic effects as detailed in Section 11.4, it is considered possible that oiling from a release of hydrocarbons could significantly impact ecosystems (i.e. there could be a significant adverse impact on the favourable conservation status of relevant species and/or habitats in areas identified to be at risk from oiling); these impacts would likely constitute a MEI.

As outlined in Sections 11.4.5 to 11.4.8, the most significant threat to Annex I habitats, Annex II/IV species, and MPA features arises from the severity of surface oiling. MPAs designated for protection of seabirds are especially vulnerable due to the sensitivity of these species to oil contamination. According to Table 11.13, the protected features / qualifying species from 53 MPAs (33 x SPA; 9 x SAC; 5 x RAMSAR; 5 x NC MPA; 1 x MCZ) are at Medium risk from a large-scale oiling event which could adversely impact their conservation objectives.

It should be stressed that the identified major accident scenario is an extreme worst case; it assumes the complete failure of all control and preventative measures. In a real situation, steps would immediately be taken to stem the flow of hydrocarbons and in the event of a well control incident bring the well back under control.

11.6 Mitigation Measures

Serica's commitments to ensuring protection of the environment are set out in Serica's corporate HSE policy. Serica follow the ISO 14001 standard and has an externally verified EMS.

Serica has Oil Spill Response Limited (OSRL) membership which provides access to well capping devices to contain the well. Serica has insurance provisions in place to cover well control/re-drill situations as well as legal liabilities, and the Company is a member of Offshore Pollution Liability Agreement (OPOL) which provides rapid compensation to parties directly affected by an oil spill.

It is the policy of Serica that the Kyla Development will be designed and operations will be conducted in such a manner as to minimise the risk of accidental releases. Onshore design reviews, risk assessments and operations planning are used to identify potential risks and to ensure that, where possible, risks are minimised at the design stage. Where residual risks remain, mitigation procedures will be put in place to prevent accidental spills. Key mitigation measures for the Kyla Development are summarised in Table 11.14.

MODU and vessel contractors will be required to demonstrate that they have control processes in place to minimise environmental impacts. Training, competency and maintenance of safety and environmentally critical equipment all play vital roles in ensuring the risks of pollution are as low as reasonably practicable.

An approved OPEP will be in place, prepared in advance of activities commencing offshore, which will detail the spill prevention measures, response procedures and resources available to Serica in the event of a spill. All supporting vessels will also have a ship oil pollution emergency plan (SOPEP) onboard.

Table 11.14: Key Spill Prevention Measures for the Kyla Development

Source	Spill Prevention Measures
Loss of chemicals, fuel or utility hydrocarbons during bunkering and general operations	• Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas; • Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories; • Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system; • Chemical, utility and fuel storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent spills overfilling these storage tanks; • Small spill kits will be on board the MODU to clean up deck spills and prevent spilt hydrocarbons and chemicals from reaching the sea;

Source	Spill Prevention Measures
	• Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme; • Bunkering procedures will be put in place to include measures such as transfer operations to be supervised at all times from both the supply vessel and MODU; • Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills; • Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment; • Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering; • Use of floating hoses during bunkering operations; • Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions.
Loss of containment on MODU due to collision or other major event	• Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008; • 500m exclusion zone will be designated around the MODU; • Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the safety zone; • Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices e.g. Kingfisher Bulletin. • The drilling rig TOOPEP or CIP will be in place, and the Kyla Field OPEP will fall under both the Triton Field OPEP (pipeline rupture) and the Petrofac Field OPEP (well incident), including modelling and appropriate response planning
Well Blowout	• Crews will be adequately experienced, trained in well control techniques and supervised; • Weighted drilling fluids will provide the primary barrier and the downhole pressures will be carefully controlled and monitored; • The secondary barrier will be the BOP which will be regularly maintained and tested; • Well design and construction reviewed by an independent well examiner; • Safety and Environmental critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each; • Emergency drills will be held regularly; • Emergency response plans and equipment will be in place; • Review spill mitigation measures of all contractors as part of the contractor selection process.
Loss of pipelines	• Where practicable, pressure and leak testing will be undertaken onshore prior to infrastructure being installed. All pipelines will be pressure tested to above the planned operating pressure; • Routine monitoring of pipeline pressure and temperature will be undertaken. Automatic and manual shutdown systems in place; • Regular ROV inspection of all pipelines will be undertaken.

11.7 Residual Risk

Based on historical data and taking into account the spill prevention measures that will be in place, the most probable accidental releases from the proposed Kyla Development will be small in volume. It is considered to be extremely rare for a major event, such as a blowout, to occur, particularly given the measures that will be in place to reduce the probability of a failure of well control. The consequences of an accidental release from the Kyla Development will vary depending on the quantity and type of hydrocarbon released, the wind speed and direction and sea state and the sensitivity of receptors

depending on the time of year. A small spill of oil or diesel would be subject to rapid dilution and dispersion and any impact on receptors in the marine environment would be short term and localised.

The Kyle crude is an ITOPF Group 2 (37.8° API) oil that undergoes rapid evaporation, dispersion and biodegradation upon release. Although modelling indicates that ca. 17 % of the released mass remains within the water column at the end of the 142-day simulation (Table 11.11), concentrations decline quickly following cessation of the blowout, and the oil is not predicted to persist in the water column, at the sea surface, or on the shoreline. The residual risk to the marine environment from a worst case accidental release is considered to range from **Medium** to **Low**, depending on the receptor impacted, but in all cases the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant.

11.8 Transboundary Impacts

The Kyla field lies approximately 72 km west of the UK / Norwegian median line (which represents the nearest international boundary). As such, stochastic modelling predicts a 100 % probability of surface and subsurface oil crossing the Norwegian median line. The minimum time for surface and subsurface oil to reach the Norwegian median line is 78 hours and 74 hours, respectively (refer to Table 11.6).

In addition, there is a high probability (up to 83 %) of surface oiling is predicted in Danish waters, while moderate probabilities (up to 56 % and 69 %) occur in German and Swedish waters respectively (Table 11.6). The probability of surface oil entering Dutch waters remains comparatively low (≤41 %) (Table 11.6). Seasonal variability is notable, with the greatest transboundary transport predicted in winter and autumn, reflecting enhanced wind-driven spreading and deeper mixing during these periods.

Model outputs predict that only UK waters are likely to experience BAOAC 5 (Continuous True Oil Colour) and BAOAC 4 (Discontinuous True Oil Colour) surface oiling. In contrast, BAOAC 3 (Metallic) and BAOAC 2 (Rainbow) thresholds may be reached within Dutch, German, Danish, Norwegian and Swedish waters (refer to Figure 11.2).

It is important to note, however, that the scenario modelled is an extreme worst case; it assumes the complete failure of all control and preventative measures. In a real situation, steps would immediately be taken to stem the flow of hydrocarbons and bring the well back under control. A counter-pollution response strategy would also be developed and initiated.

Agreements are also in existence for dealing with international releases with states bordering the UK (e.g. Bonn Agreement). These agreements would operate within the framework of the National Contingency Plans (NCPs) and are oriented towards major releases. In the event of an oil spill entering Norwegian waters, the NORBRIT Agreement (the Norway-UK Joint Contingency Plan) may be activated. Responsibility for implementing joint action with neighbouring states rests with the ACA of the country on whose side of the median line a spill originated. The UK's ACA is the Counter Pollution Branch of the MCA.

Given the above, the risk of transboundary impacts is considered to range from **Medium** to **Low**, depending on the receptor impacted, but in all cases the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant.

11.9 Cumulative Impacts

Cumulative effects from accidental releases are not anticipated. As indicated by historical data, the likelihood of one major accidental release occurring is remote or extremely remote, limiting the cumulative impact from the Kyla Development and other existing installations.

12 Waste Management

12.1 Introduction

The management of waste produced offshore on the UKCS is regulated through a framework of international and national legislation. Waste generated on offshore installations and vessels is primarily regulated by the Merchant Shipping (Prevention of Pollution by Sewage from Ships) Regulations 2020 (as amended) and Merchant Shipping (Prevention of Pollution by Garbage from Ships) Regulations 2020 (as amended). These Regulations implement Annex IV (Prevention of pollution by sewage from ships) and Annex V (Prevention of pollution by garbage from ships) of MARPOL 73/78 (The International Convention for the Prevention of Pollution from Ships).

MARPOL Annex IV and V prohibit the discharge of all garbage (including plastics) and galley waste (except for comminuted or ground food waste to < 25 mm and treated sewage) into sea from offshore installations or vessels. Once transported onshore, waste management is regulated by the Environment Protection Act 1990 (as amended), which sets out Duty of Care requirements for the containment, transfer, handling, and recording of all onshore waste through appropriately licensed carriers holding a Waste Carrier Registration. In Scotland, the Scottish Environment Protection Agency (SEPA) is responsible for regulating waste management.

Given the subsea nature of the Kyla Development, the majority of waste associated with the Project will be generated onboard the vessels, including the MODU, contracted by Serica to undertake the development operations. Waste handling onboard the vessels, including the MODU, will therefore be the responsibility of vessel/MODU contractors. However, Serica has a Duty of Care to ensure that the collection, handling, and disposal of all waste generated by the Kyla Development is achieved, in compliance with current environmental legislation, as well as in accordance with Serica's Waste Management Procedures.

12.2 The Waste Hierarchy

Serica is committed, and has a legal duty, to take all reasonable steps to apply the waste hierarchy (as illustrated in Figure 12.1) and promote 'high quality' recycling.

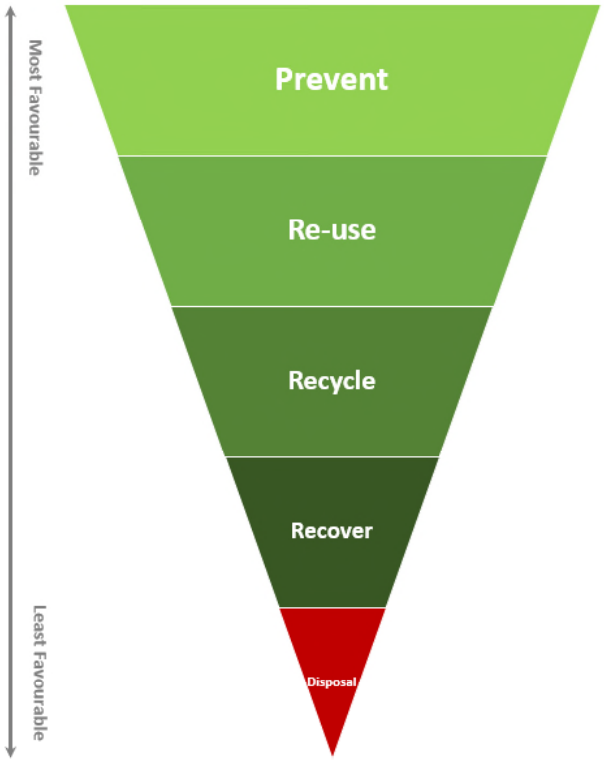


Figure 12.1: Waste Hierarchy

The waste hierarchy ranks waste management options according to the best environmental outcome, taking into consideration the lifecycle of the material. The lifecycle of a material is an environmental assessment of all the stages of a product's life from-cradle-to-grave (i.e. from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). Waste will only be disposed of if it cannot be prevented, re-used, recycled or recovered.

In its simplest form, the waste hierarchy gives top priority to preventing waste. When waste is created, it gives priority to preparing it for reuse, then recycling, then other recovery, and last of all disposal (i.e. landfill). For example, one tonne of food waste in landfill produces 450 kg CO_2e, whereas preventing one tonne of food waste saves 3,590 kg CO_2e. The benefits of selecting options higher up the hierarchy also extend beyond carbon savings and include reduced water consumption, protection of important raw materials, creation of jobs, and other economic opportunities (Scottish Government, 2017).

12.3 Duty of Care

Anyone who produces, transports, manages and treats waste has a legal Duty of Care to ensure that waste is managed correctly. This includes proper storage, only transferring it to an appropriate person and ensuring that when it is transferred it is sufficiently well described to enable its safe recovery or disposal without harming the environment.

Serica will ensure that all waste produced from the Kyla Development operations will be minimised through appropriate procurement controls and will be properly segregated for recycling, treatment or disposal. Bulk wastes generated offshore will be segregated by type and periodically transported to shore in an auditable manner through authorised and licenced waste contractors.

Serica is responsible for ensuring that waste is transferred to waste contractors in possession of a Waste Carrier Registration. All controlled waste being transferred onshore is required to have a completed Transfer Note, whilst special waste requires a Consignment Note. These Notes provide details on the type and quantity of waste that is being transferred, the parties involved in the transfer of waste, the category of authorised person in receipt of the waste, licence numbers, and time, place and date of transfer. Once onshore, waste will be managed in accordance with the waste hierarchy and will be recovered or disposed of at appropriate licensed sites by properly licensed waste disposal contractors.

12.4 Waste Streams

The types of wastes likely to be generated during the life of the Kyla Development are summarised in Table 12.1 and include both non-hazardous waste and hazardous waste (referred to as special waste in Scotland).

Table 12.1: Types of Waste Likely to Generated from the Kyla Development

Special Waste	General Waste	Other Waste	Backloaded Cuttings [1]	NORM [2]
Oils, paints, adhesives, solvents, hazardous chemicals and brines, batteries, oily rags	Non-hazardous workover / completion / drilling fluids, brines Segregated recyclables (e.g. scrap metal, plastics, aluminium cans, paper / cardboard, glass etc.) Non-hazardous, galley waste, accommodation waste, compactor waste	Clinical materials Explosives	LTOBM cuttings Solid material (e.g. powder or stabilised products), oil and water generated by the treatment process. These will be skip and shipped back to shore for onshore processing and disposal	Naturally occurring radioactive material (NORM) from mineral scales which build up in pipework

[1] LTOBM cuttings may be backloaded for treatment onshore or processed offshore using a thermal cuttings treatment unit to an acceptable overboard disposal limit (<1% OOC) and discharged to sea (refer to Section 2.6.2).
[2] May be applicable during Kyla decommissioning operations. Where NORM readings are found, the infrastructure would be subject to specific identification, handling and waste disposal at an authorised site in accordance with legislative requirements.

Given the subsea nature of the Kyla Development, the majority of waste will be generated onboard the MODU during development drilling operations and, on cessation of production, when the Kyla infrastructure is decommissioned. See further detail below.

The quantities and disposal routes of waste arising from offshore operations associated with the Kyla Development will be reported by Serica via the OPRED EEMS, which records measured and calculated data relating to emissions and discharges from offshore installations.

12.4.1 Vessel Waste

Waste will be generated onboard all vessels associated with the proposed Kyla Development activities including the MODU and support vessels, subsea installation vessels and any vessels used during inspection and maintenance activities and decommissioning. All vessel waste will be managed in compliance with the framework of Regulations discussed above and in line with individual vessel specific Waste Management Plans (WMPs). Generally, waste will either be discharged in line with MARPOL 73/78 requirements, if appropriate, or it will be segregated and stored in suitable, labelled containers for subsequent transfer to shore, where it will be treated or disposed of in accordance with the waste hierarchy.

Offshore vessels of 100 gross tonnage and above, and every ship certified to carry 15 or more persons, must have a Garbage Management Plan and maintain a Garbage Record Book (as per MCA Marine Guidance Note 632 (M+F) Amendment 2). Solid domestic waste will normally be compacted with a garbage compactor, placed in disposal bags and returned to the mainland in waste skips. Open skips will be netted. Separate storage areas will be provided for solid and liquid waste that can be reused. Waste storage areas will be well ventilated and bunded with drainage to appropriate storage or treatment areas. Hazardous waste containers will be covered to reduce rainwater contact in the containment structure. Furthermore, segregation of recyclable materials will be implemented to avoid contamination and consequent reduction of the quality of recycled products.

12.4.2 Drilling Waste

MODUs generate various waste products during routine drilling operations (e.g. excess cement, used drilling fluids and chemicals etc.), in addition to waste generated from the everyday running of the MODU (e.g. general waste, food waste and sewage).

Wastes will be minimised by use of appropriate procurement controls, and all wastes will be segregated for recycling, disposal, and / or treatment. The appointed waste management contractor will supply monthly reports of all waste sent to shore and will complete Controlled Waste Transfer Notes as required, and records of monthly disposals will be maintained. Waste Management Duty of Care audits will also be carried out.

Oily waste will be generated on the MODU by a variety of sources, including waste engine oil and hydraulic oil. All waste oil will be held in designated storage tanks. The volumes of waste oils kept onboard the MODU will be kept to a minimum before being transferred to shore, keeping the possibility of spillages to a minimum. No sludge or waste oil will be discharged to sea. Lidded skips will be used for LTOBM contaminated drill cuttings (if required).

12.4.3 Decommissioning Waste

Onshore waste management will be in an important consideration during the decommissioning phase of the Kyla Development. A dedicated decommissioning WMP will be produced to identify all waste streams and the most appropriate removal and disposal method. All recovered waste will be brought to shore to a licenced specialist decommissioning waste facility. Where possible, materials will be sold for reuse or recycled in accordance with the waste hierarchy.

12.5 Mitigation Measures

The management of offshore waste generated on the UKCS is strictly regulated, ensuring a high level of mitigation from the outset, as described above. Serica will ensure successful implementation of the mitigation measures regarding waste management by:

- Application of the Waste Hierarchy to all produced waste;
- Compliance with Serica's WMP and use of Garbage Management Plans for the management of waste produced from vessels;
- Compliance with Serica's Waste Management Procedures for waste produced during the proposed development activities;
- Segregation, transfer onshore and disposal of waste through licensed contractors and sites.

12.6 Conclusion

Several different waste streams will be generated throughout the lifespan of the Kyla Development. Waste management will be undertaken in compliance with current environmental legislation and applicable waste procedures which includes the waste hierarchy, as described above. The management of offshore waste generated on the UKCS is strictly regulated and the UK has well-established infrastructure in place to manage this waste effectively. Therefore, no significant impacts (including cumulative or transboundary impacts) are expected as a result of the Kyla Development.

13 Environmental Management

13.1 Serica's EMS

Serica Energy Chinook Limited (Serica) is a subsidiary of Serica Energy plc and operators under the Group's policies. Serica is committed to conducting its business activities in a manner that assures the health, safety and well-being of our staff and contractor personnel whilst also safeguarding the environment within which we operate.

Serica's OMS provides the framework for systematic management of HSEQ across the Serica organisation and is designed to ensure the delivery of safe, environmentally responsible, and reliable operations in accordance with defined policies, practices, procedures and standards. Copies of Serica's HSEQ and ESG Policies are provided in Figure 13.1 and Figure 13.2, respectively.

The structure and content of the OMS recognises the principles of ISO 14001 (Environmental Management Systems) and ensures that risks to the environment are reduced to ALARP.

Serica's EMS was successfully verified against the requirements of OSPAR 2003/5 to Promote the Use and Implementation of Environmental Management Systems by the Offshore Industry in April 2025 by ERM CVS Limited. In accordance with the requirements of OSPAR 2003/5, the EMS:

- Is implemented at a strategic level and integrated into corporate plans and policies;
- Identifies the organisation's impacts on the environment and sets clear objectives and targets to improve its management of these aspects and the organisation's overall environmental performance;
- Is designed to deliver and manage compliance with environmental laws and regulations on an ongoing basis, and to quickly initiate corrective and preventative action in cases of legal non-compliance;
- Delivers good resource management;
- Incorporates assured performance metrics that demonstrate the above and can be communicated in a transparent manner;
- Delivers continual improvement.

The EMS covers aspects of environmental management, such as chemical management, pollution prevention and control, and emissions management. It is designed to achieve Serica's corporate expectation to implement best practice above and beyond the requirements of the regulations.

Key to this ambition is the Company's commitment to reduce GHG emissions from its operations in line with the global transition to a low carbon economy and the UK Government's Net Zero targets. In 2024, Serica progressed key GHG emissions reduction projects aimed at reducing the Scope 1 emissions generated from the Bruce installation and worked with our partners to progress emissions reductions on non-operated assets. Further information on Serica's GHG emissions performance is provided in Section 9.

All Serica's operations and projects, including the proposed Kyla Development, have the potential to impact on the environment and they are all subject to strict environmental regulatory controls which require Serica to prepare and submit regulatory applications to gain approval before activities commence. Serica will appoint a Well and Pipeline Operator for the Kyla Development under the Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015, subject to approval by the NSTA.

The company constantly monitors operational activities and reports ongoing emissions, discharges and waste streams to ensure regulatory requirements are met and ensure there is no significant impact on the environment. In the event of an unplanned release/spill to sea, or a non-compliance with regulatory requirements, the relevant regulatory authorities would be notified and immediate actions taken to respond to any threat of or actual pollution. Investigations of incidents are conducted to gain any learnings or actions to prevent recurrence.

Serica is committed to continually improving environmental performance through responsible design, development and operations. For the Kyla Development, the environmental performance of contractors will be a key consideration. To this end, every effort will be made to select contractors with strong HSEQ performance and processes. Serica will also ensure that all parties engaged in the proposed Kyla Development operations understand the potential environmental impacts and commitments as outlined in this ES (refer to Section 13.2) and the importance of environmental compliance.

The company records and monitors their environmental data in line with regulatory reporting requirements. Environmental performance data for each of Serica's operated assets and associated activities is submitted to the UK environmental regulator (OPRED) via the EEMS.

Serica's Board of Directors provides support, guidance and oversight to the Company's activities in the area of ESG, in particular through the Sustainability Committee. We continue to refine our approach to climate-related risk management to ensure we are identifying and managing material risks, which is highlighted in our Taskforce on Climate-related Financial Disclosures (TCFD) Summary Report.

Figure 13.1: Serica HSEQ Policy Statement

SERICAENERGY

HEALTH, SAFETY, ENVIRONMENTAL AND QUALITY POLICY

Our Commitment

Serica is committed to conducting its business activities in a manner that assures the health, safety and well-being of our staff and contractor personnel whilst also safeguarding the environment within which we operate.

Principles

Serica's Operations Management System (OMS) provides an integrated and systematic approach to Health, Safety, Environmental and Quality (HSEQ) management and demonstrates how we:

- comply with all applicable legislation, industry standards and good practice
- promote a positive HSEQ culture through visible leadership commitment, personal accountability, communication and engagement with key stakeholders
- understand our risk profiles and apply a risk management process that reduces this risk to As Low As Reasonably Practicable (ALARP)
- ensure that HSEQ remains integral to the planning, design, construction, operation, maintenance and disposal of our assets
- promote environmental sustainability and the reduction of our carbon footprint
- provide staff with suitable information, instruction and training relevant to their duties and responsibilities
- maintain emergency response plans and the organisational capability to respond effectively to incidents and emergencies
- continually improve our HSEQ performance by defining performance objectives, monitoring and measuring results, and completing a programme of audit and assurance activities

Serica expects everyone involved in our activities to take responsibility and be accountable for compliance with this policy, our OMS, current legislation and all applicable regulatory requirements.

The Chief Executive Officer, supported by the Board of Directors, is accountable for the HSEQ performance of the company and shall ensure that sufficient resources are in place to implement this policy.

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Figure 13.2: Serica ESG Policy Statement

SERICAENERGY

ENVIRONMENTAL, SOCIAL, GOVERNANCE (ESG) POLICY

Our Commitment to Act Responsibly

We play our part in the energy transition by finding, developing and producing oil and gas in a socially and environmentally responsible manner. We aim to progressively reduce our environmental impact, promote the wellbeing of our staff, support the communities in which we operate and carry out our business in accordance with applicable laws and high standards of governance.

Our ESG Policy Highlights Our Key Principles:

Environment:

- Reduce our Scope 1, 2 and 3 emissions in line with applicable industry targets
- Pursue and implement effective, innovative and sustainable technologies through collaboration and investment
- Minimise the impact of our waste streams by careful planning, working with our suppliers and championing a circular economy
- Lower our impact on the marine environment and protect and restore biodiversity where practicable

Social:

- Prioritise the health, safety, and wellbeing of our staff and contractors in line with our HSEQ Policy
- Create an inclusive, diverse and learning culture, where people can be their true selves at work
- Train and develop our teams to help them reach their full potential
- Make a positive impact within our local communities and wider society through charitable donations, volunteering and knowledge-sharing

Governance:

- Act in accordance with applicable governance codes and practices
- Excel in transparent reporting by adopting internationally recognised frameworks and engaging with stakeholders
- Assess and mitigate sustainability-related risks associated with our operations
- Utilise ESG screening criteria when exploring new business opportunities

Our ESG Policy and ESG Strategy are contained within the Operations Management System (OMS). We expect everyone involved in our activities to take ownership of their actions and ensure that they comply with our ESG policy, our OMS, current legislation and any applicable regulatory requirements. Our CEO, with the support of our Board of Directors, owns this policy and is ultimately responsible and accountable for Serica's ESG performance.

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13.2 ES Commitments

Table 13.1 summarises the mitigation measures and commitments identified within this ES. As described above, Serica will ensure these are taken into account and implemented as the proposed Kyla Development progresses.

Table 13.1: Mitigation Measures and Commitments Register

Ref	Theme	Mitigation Measure / Commitment	ES Section
1	Physical Presence	a. If required, a guard vessel will be implemented to protect the pre-laid anchors and mooring chains from interaction with fishing vessels. b. 500 m safety zone will be designated around the MODU and a dedicated ERRV, equipped with AIS and/or ARPA will be present during the drilling operations to monitor movements of other vessels in the area and prevent them entering the safety zone. c. A Vessel Traffic Survey and, if necessary, a Collision Risk Assessment, will be prepared to support the CtL permit applications required to site the pre-laid anchors and mooring chains, MODU and subsea infrastructure at the Kyla Development location and all vessels will comply with COLREG. d. Information on the location of the MODU, MODU anchor positions, 500m safety zone, subsea infrastructure (i.e. wellhead/tree, valve skid and pipelines) and vessel operations will be communicated to other sea users via the UKHO, MCA, FishSAFE, Kingfisher Information Services, Notices to Mariners and Radio Navigation Warnings. e. Serica will continue to consult with SFF during the detailed design phase and planning process for the subsea infrastructure installation activities. A FLO will be appointed to maintain good communication with local fisheries and co-ordinate activities, particularly during installation of the pipelines and umbilical. f. Through careful planning, the number of vessels and length of time they are required on site for installation operations, will be reduced as far as practicably possible. g. Where boulders (>0.5 m) are required to be removed from the pipeline lay corridors, the as-left position of any relocated boulders will be recorded and reported via Kingfisher. h. Vessels involved in subsea infrastructure installation operations will update their marks, lights and navigational status broadcast on AIS to indicate when they are restricted in manoeuvrability. This will assist any passing vessels that encounter the installation vessels. i. Pipeline working corridors will be minimised, as far as possible. j. Prior to installation, Serica will apply for a 500 m safety zone to be in place around the subsea infrastructure at the Kyla well location. The subsea infrastructure at the Kyla well location will be designed to be 'fishing friendly'. k. Following pipeline trenching and burial operations, Serica will liaise with the SFF to ameliorate any safety risks for the fishermen from mud berms being left behind. l. During the life of the field, external inspection of the pipelines and control umbilical will take place at a frequency determined by ongoing risk assessment. Any free spans recorded that present a potential hazard to fishing will be rectified by rock placement.	6

Ref	Theme	Mitigation Measure / Commitment	ES Section
2	Seabed Disturbance	a. Use the optimised number of MODU anchors and length of ground chains to maintain stability and integrity. b. MODU anchors will be set at the optimum angle for the local seabed sediments, reducing the potential drag across the seabed and helping them to become suitably embedded; c. The MODU mooring system (anchors and chains) will be placed in accordance with site survey results so as to prevent damage to sensitive seabed habitats. d. A full CHARM assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing and, as part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings). e. If deemed feasible, thermal cuttings treatment will be used to treat the LTOBM contaminated cuttings from Kyla to an acceptable overboard disposal limit (<1% oil on cuttings) or alternatively LTOBM cuttings will be skipped and shipped for disposal onshore. f. A ROV and chemical dye will be used to monitor cement returns when cementing both the conductor and 20" casing to help ensure the volume of cement discharged to the seabed is kept at a minimum. g. Route selection and optimisation will be based on acquired Environmental, Geophysical, and Geotechnical survey data. h. The width of the working corridors during pipeline and umbilical installation operations will be minimised as far as possible. i. Any boulders removed from the pipelines and umbilical lay corridors will be placed appropriately on the seabed to avoid a snag hazard and their as-left position recorded. j. Use of DP installation vessels (where applicable) as opposed to anchored vessels. k. Rock will be deployed from a DP rock dumping vessel using a fall pipe and the rate and locations of deployment will be controlled on board the vessel and monitored using high resolution survey / sonar equipment. l. Size of subsea infrastructure will be optimised for the Kyla Development. m. Subsea infrastructure layout, trench transitions and pipeline crossing designs optimised to minimise material deposited. n. Monitoring of integrity of subsea infrastructure, including the pipelines / umbilical and stabilisation material throughout production operations and taking remedial action, if required. o. Minimise amount of deposited material whilst still achieving the required level of stabilisation / protection.	7
3	Noise	a. The piling operations will follow the JNCC protocol for minimising the risk of injury to marine mammals from piling noise (JNCC, 2010b). b. Use of properly qualified, trained and equipped MMOs or PAM operatives to detect marine mammals within a 500 m "mitigation zone" and potentially recommend a delay to piling operations. MMOs / PAM operatives will carry out a 30 minute pre-piling survey and if an animal is detected then work should be delayed until it has left the area; c. If piling is to be carried out at night or in poor visibility, PAM will be used to carry out the 30-minute pre-piling survey;	8

Ref	Theme	Mitigation Measure / Commitment	ES Section
		d. If deploying PAM, Serica will also ensure that contractors implement the JNCC guidance for the use of Passive Acoustic Monitoring in UK waters (JNCC, 2023); e. Soft-start of piling, whereby there is an incremental increase in power and, therefore, sound level. This should be carried out over a minimum period of 20 minutes. This is believed to allow any marine mammals to move away from the piling location and reduce the likelihood of exposing the animal to sounds which can cause injury; and f. Repeat of the pre-piling survey and soft-start whenever there is a break in piling of more than 10 minutes.	
4	GHG Emissions	a. Drilling project management contractor (Petrofac) standard emissions reduction measures includes logistics optimisation (minimise unplanned sailings and flights). b. Selection of MODU for Kyla drilling will consider if Energy Control System is implemented on the rig to monitor the energy consumption to deliver substantial reductions in CO_2 and NOx by optimising operations. MODU operator to be ISO 140001 (Environmental Management) and ISO 50001 (Energy Management) certified by DNV. The rig will be moored during operations which has a lower fuel usage than operating on DP. c. During contracting of services, Serica/Petrofac will enforce ESG compliance and reduction information from potential suppliers. Responses to these items will be evaluated and applied as part of the service contract awards. d. Electrical powerpacks, instead of diesel powerpacks, will be used for all services on the MODU where these are compatible/available. e. The Kyla well will be planned and designed to minimise Non-Productive Time and Waiting on Weather which limit the overall emissions during well operations. f. Only Tier 1 subsea installation contractors will be shortlisted in the tendering process. g. Vessels proposed for use during the Kyla Development will be assessed against fuel consumption as part of the tender assessment process. h. Serica, as the operator of Kyla, will support the Triton FPSO operator as they continue to assess and implement reasonable decarbonisation strategies for Triton FPSO.	9
5	Marine Discharges	a. A chemical risk assessment will be undertaken to identify the risk profile of chemicals to be used and / or discharged in accordance with the requirements of the Offshore Chemicals Regulations 2002 (as amended 2011). Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile; b. Chemical use and discharge will be minimised; c. For assessment purposes, thermal cuttings treatment is being evaluated to treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% oil on cuttings). If not selected / considered to be feasible, the LTOBM contaminated cuttings would be skipped and shipped onshore for disposal; d. During the drilling operations, any discharges of residual LTOBM hydrocarbons will be treated to meet oil in water limits of the Chemical Permit SAT. The discharge streams will also be monitored and sampled in accordance with the permit conditions;	10

Ref	Theme	Mitigation Measure / Commitment	ES Section
		e. During the production operations, any discharges of residual reservoir hydrocarbons in the produced water stream will be treated to meet oil in water limits of the Triton Oil Discharge Permit SAT. The discharge streams will also be monitored and sampled in accordance with the permit conditions.	
6	Accidental Discharges	a. Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas; b. Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories; c. Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system; d. Chemical, utility and fuel storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent spills overfilling these storage tanks; e. Small spill kits will be on board the MODU to clean up deck spills and prevent spilt hydrocarbons and chemicals from reaching the sea; f. Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme; g. Bunkering procedures will be put in place to include measures such as transfer operations to be supervised at all times from both the supply vessel and MODU; h. Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills; i. Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment; j. Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering; k. Use of floating hoses during bunkering operations; l. Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions. m. Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008; n. 500m safety zone will be designated around the MODU; o. Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the safety zone; p. Notifications made to ‘regular runners’ and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices e.g. Kingfisher Bulletin. q. The drilling rig TOOPEP or CIP will be in place, and the Kyla Field OPEP will fall under both the Triton Field OPEP (pipeline rupture) and the Petrofac Field OPEP (well incident), including modelling and appropriate response planning. r. Crews will be adequately experienced, trained in well control techniques and supervised; s. Weighted drilling fluids will provide the primary barrier and the downhole pressures will be carefully controlled and monitored; t. The secondary barrier will be the BOP which will be regularly maintained and tested; u. Well design and construction reviewed by an independent well examiner;	11

Ref	Theme	Mitigation Measure / Commitment	ES Section
		v. Safety and Environmental critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each; w. Emergency drills will be held regularly; x. Emergency response plans and equipment will be in place; y. Review spill mitigation measures of all contractors as part of the contractor selection process. z. Where practicable, pressure and leak testing will be undertaken onshore prior to infrastructure being installed and all pipelines will be pressure tested to above the planned operating pressure; aa. Routine monitoring of pipeline pressure and temperature will be undertaken. Automatic and manual shutdown systems in place; bb. Regular ROV inspection of all pipelines will be undertaken.	
7	Waste Management	a. Application of the Waste Hierarchy to all produced waste; b. Compliance with Serica's Waste Management Plan and use of Garbage Management Plans for the management of waste produced from vessels; c. Compliance with Serica's Waste Management Procedures for waste produced during the proposed development activities; d. Segregation, transfer onshore and disposal of waste through licensed contractors and sites.	12

14 Conclusions

Serica is proposing to develop the Kyla field via a single subsea well tied back via 12 – 13.2 km long production pipeline, gas lift pipeline and umbilical to one of the existing Bittern drill centre manifolds (either DCA or DCB). The Bittern manifolds are in turn tied back to the Triton FPSO, with both assets operated by Dana Petroleum E&P Limited (Dana). Kyla hydrocarbons will be processed on the Triton FPSO with Kyla oil exported as part of the Triton FPSO blend via shuttle tanker and sales gas routed with other Triton area gas to the St Fergus terminal onshore via the Fulmar gas pipeline.

Under The Offshore Oil and Gas Exploration, Production, Unloading and Storage (EIA) Regulations 2020, as the proposed Kyla Development will extract more than 500 tonnes of oil per day, there is a mandatory requirement for Serica to conduct an EIA to determine if the proposed Kyla Development is likely to have any significant effects on the environment, the results of which have been documented in this ES.

The key findings of the EIA undertaken for the Kyla Development are summarised below.

14.1 Physical Presence

No significant residual effects on other sea users (shipping and commercial fishing) are predicted as a result of the physical presence of the semi-submersible MODU (including pre-laid anchors and ground chains) and / or vessels during Kyla drilling, installation, inspection and maintenance and decommissioning activities or the long-term presence of the Kyla subsea infrastructure and associated protection / stabilisation material.

The Kyla Development has the potential to interact with shipping through the temporarily presence of the MODU and / or vessels resulting in the displacement of vessel traffic and increased risk of a vessel collision. The greatest impact will be before and during drilling operations, during installation of the subsea infrastructure and, following cessation of production, during decommissioning operations. However, any discernible increase in vessel presence in the area will be temporary in nature. The risk of a collision will be minimised by implementing measures, including temporarily establishing a 500 m safety zone around the MODU during the proposed drilling operations, which will be patrolled by an ERRV equipped with an AIS and/or ARPA. Notifications to other sea users will also be issued via Notices to Mariners and Kingfisher Bulletin to communicate the location of the works. A VTS will be undertaken to inform the CtL permit applications, required to moor the MODU and site the subsea infrastructure at the Kyla location. If necessary, a Collision Risk Assessment may also be undertaken. Residual effects on shipping from the physical presence of the DP MODU and vessels during drilling, installation, inspection and maintenance and decommissioning activities, are therefore **Minor** and not significant.

Fishing vessels may be temporarily displaced from the Kyla Development area during the drilling and installation phases of the Project, with an area of 0.8 km^2 at the Kyla drill centre location also lost for the life of the field development. This is a very small area in comparison to the alternative fishing grounds available in the wider CNS area, particularly as the area surrounding Kyla is subject to relatively low levels of fishing activity. In addition, the proposed Kyla Development presents a snagging risk to commercial fishing vessels. The MODU anchors and mooring lines will be pre-laid on the seabed for a number of weeks ahead of MODU arrival and will remain in place for a number of weeks following the MODU departure. To reduce the snagging risk during this period, if required a guard vessel will be used to deter vessels from the area, thereby preventing potential interaction with the mooring lines while the MODU is not on location. During subsea installation activities, the main risk of snagging will be after pipe lay, pending trenching and burial. To minimise this risk, whilst installation activities are ongoing, a guard vessel will be used to patrol the length of the lines. To further reduce the risk of snagging; the Kyla xmas tree and Kyla valve skid, as well as the potential tie-in structure at Bittern (which will be located within an existing 500 m safety zone) will be designed to be 'fishing friendly'. Where concrete mattresses are used as part of the pipeline crossings design, or in other open water locations outside the 500 m safety zones at Bittern and Kyla, rock cover will be provided to minimise risk of snagging with fishing gear. Residual effects on commercial fishing from the physical presence of the DP MODU and vessels during drilling, installation, inspection and maintenance and decommissioning activities, are therefore **Minor** and not significant.

The proposed Kyla Development is located within a region of established oil and gas activity. Other oil and gas developments in the area will utilise vessels which have the potential to act cumulatively in increasing vessel collision risk. However, given the mitigation measures which will be in place for the Kyla Development and other oil and gas operations, increased vessel presence should not act in combination with any other development to increase collision risk.

A significant cumulative increase in snagging risk with other oil and gas development in the area is also not anticipated as the Kyla subsea infrastructure will be designed to be 'fishing friendly'; the pipelines and umbilical will be trenched and buried, and the berm profile of any rock placement will be designed to be overtrawlable.

14.2 Seabed Disturbance

No significant residual effects on seabed sediments, seabed communities or fish are predicted as a result of disturbance to the seabed during the life of the Kyla Development. The worst case total area of seabed that will be impacted temporarily by the Kyla Development is estimated at around 0.819 km^2, and the worst case total area of seabed that will be impacted in the long term by the Kyla Development is estimated at around 0.115 km^2. These are relatively small areas in comparison to the seabed available in the CNS region, with similar water depths, sediment types and benthic communities. Of note, the Kyla Development area is not located within or near to an MPA. The closest site, the East of Gannet and Montrose Fields NC MPA, designated for the protection of ocean quahog aggregations, is located 13.4 km north of the Kyla location.

Temporary disturbance of the seabed is attributed to the mooring of the MODU, discharge of drill cuttings, muds and cement and installation of the Kyla subsea infrastructure, including the pipelines and umbilical.

The discharge of drill cuttings, muds and cement will initially alter the seabed topography and sediment structure of a small area in close proximity to the proposed Kyla well (0.12 km^2). The accumulation of drill cuttings and mud at the Kyla drill centre is likely to change the benthic community in the immediate area by burying some animals and impairing the feeding and respiration of others. It is expected that any communities in the immediate vicinity of the well will be lost, and that increased concentrations of suspended particles near the seabed may also impair respiratory and feeding processes, inducing metabolic stress and reducing growth and survival rates. Field studies have shown however that recovery of benthic communities impacted with water based drilling discharges (which will be discharged directly to the seabed from the top two hole sections of the Kyla well) is likely to be very rapid (i.e. within a few months). The deeper wells sections of the Kyla well will be drilled with LTOBM. In the event that the LTOBM contaminated cuttings are discharged, thermal cuttings treatment will be used to treat the cuttings to an acceptable overboard disposal limit (<1% oil on cuttings), thereby resulting in no significant changes to the natural benthic community or re-colonisation of the seabed.

Installation of the Kyla subsea infrastructure, particularly the trenching and backfill operations during pipeline and umbilical installation, will also result in temporary disturbance to seabed from sediment suspension and re-settlement within an area of ca. 0.623 km^2. However, given the relatively fine (sandy and muddy) nature of the sediment at Kyla any sediment plumes or re-suspended sediment will tend to settle quickly and will not be prolonged or affect large areas. It is acknowledged that the Kyla survey area shows some similarity to the seapen and burrowing megafauna (burrowed mud) habitat, classified as an OSPAR threatened and/or declining habitat and Scottish PMF. However, the species that inhabit this type of benthic habitat are deemed to be highly recoverable and the area impacted will be relatively small. In addition, high rates of siltation may adversely affect ocean quahog, an OSPAR threatened and/or declining species and Scottish PMF, but any mortality caused to individual specimens as a result of the proposed operations is not considered to be significant given that impacts will be highly localised.

Exposure to increased turbidity caused by the proposed Kyla Development operations may also reduce the visual acuity of fish utilising the area potentially affecting foraging behaviour. Fish may also be temporarily displaced from their spawning and nursery areas. However, given the localised area of impact and the mobile nature of the species, any displaced fish are likely to find foraging opportunities, as well as suitable spawning and nursery areas in adjacent locations. Crucially, the Kyla survey

determined that the site was unsuitable for both herring and sandeel spawning due to the sediment composition (lack of gravel for herring and high fine content for sandeel).

It is, however, recognised that some aspects of the Kyla Development (i.e. installation of the subsea structures, pipeline and umbilical, as well as associated rock and concrete mattresses for protection / stability / trench transitions) will have long term impacts on sediment communities, due to permanent habitat change, although direct physical injury of benthic species will only occur when the infrastructure or material is first placed on the seabed. This impact will last the duration of the Kyla development (ca. 8 years) and beyond depending on how the infrastructure is decommissioned. The area beneath the subsea infrastructure and protection / stabilisation material will become unavailable for re-colonisation by sandy and muddy sediment inhabiting infauna and over time a new rocky substrate habitat will become established. Ultimately, it is expected that this new habitat will be colonised by the same types of mobile and encrusting epifaunal animals already present on cobbles and boulders in the wider area. As such, any long term change to the benthic environment will be localised and is not expected to cause any widespread changes to the marine life present in the wider area.

In summary, residual effects on water quality, seabed sediments, seabed communities and fish as a result of seabed disturbance during the life of the Kyla Development are predicted to be **Negligible** to **Minor** and not significant.

Effects of seabed disturbance resulting from the proposed Kyla Development will be cumulative to those of other activities in the area. The Kyla Development is located in an area containing potential cuttings piles associated with the prior Kyle field, however, these historic cuttings piles are believed to have dispersed and now lie flush with the seabed. Seabed samples taken during the pre-decommissioning survey of the Kyle field showed a chemical footprint (elevated Total Hydrocarbon Concentration levels) covering an area of 1,432 m^2; however, this elevation is not considered to be significant contamination (Fugro, 2020; CNRI, 2021). In addition, results from the 2025 Kyla survey show all stations within the vicinity of the proposed Kyla Development area have recorded THC and heavy metal concentrations that are considered consistent with background concentrations. As such, significant cumulative seabed impacts are not predicted.

14.3 Underwater Noise Emissions

Underwater noise emissions generated during the proposed Kyla Development have the potential to disturb, or cause injury to, a number of species in the marine environment, particularly fish and marine mammals. However, the only Kyla Development activity which results in underwater noise emissions with the potential to result in significant effects on marine fauna is the potential piling operations during the installation of the valve skid at the proposed Kyla well location and the tie-in structure, if required, at the Bittern manifold. It is acknowledged that the vessels associated with drilling, subsea installation, inspection and maintenance and decommissioning operations will generate underwater noise of a continuous nature, but this will only cause temporary and localised changes in distribution of marine mammals and fish in the immediate vicinity of the vessel. In addition, the noise emissions from construction activities e.g. trenching or rock placement, are usually dwarfed by the noise emissions from the vessels themselves.

To reduce the risk of injury or behavioural disturbance to marine mammals and fish from the proposed piling operations, Serica will ensure that the JNCC protocol for minimising the risk of injury to marine mammals from piling noise is followed (JNCC, 2010b). Piling operations will therefore not commence until monitoring confirms that a 500 m “mitigation zone” is clear of marine mammals and soft-starts will be incorporated into the piling schedule design.

In summary, it is possible that short term behavioural effects may be observed among marine mammals, fish and seabirds as a result of the underwater noise emissions generated from the proposed Kyla Development, but any impacts will be mitigated such that residual effects are predicted to be **Minor** to **Negligible** and not significant.

Given the mitigation measures which will be in place for the Kyla Development, significant cumulative effects are not predicted in the event that other noisy activities are occurring nearby in the marine environment at the same time as the proposed piling operations.

14.4 Greenhouse Gas Emissions

GHG emissions generated during the development of the Kyla field will arise from the combustion of hydrocarbons for power generation on the MODU, vessels, and helicopters, referred to as 'indirect, upstream scope 3 emissions'. During the production phase, hydrocarbons from the Kyla field will be processed at the Triton FPSO with processing equipment and support facilities shared with several other producing assets. This minimises the incremental energy demand caused by the development. The incremental GHG emissions associated with processing at Triton as a result of Kyla coming online, for the purposes of this assessment, are considered to be 'direct scope 1 emissions' as Kyla production is controlled by Serica. In addition, Serica has significant interest in Triton (holding a 46% equity interest in the asset) and therefore has influence over the operator of Triton (Dana). Once the hydrocarbons have been processed on Triton and sold, oil is typically tankered to Rotterdam where oil volumes are integrated into the wider European oil sales market and converted into usable fuels such as gasoline, diesel, and jet fuel. Gas is piped from Triton to the St Fergus terminal where it enters the UK's national transmission system and is delivered to end users, such as gas-fired power stations, large industrial users, or regional gas distribution networks that connect to individual homes and businesses. Further GHG emissions will therefore arise from transportation, further processing and distribution once the Kyla hydrocarbons leave Triton, as well as from the end use of the sold product (namely, the presumption that all end use Kyla hydrocarbons are eventually combusted). Collectively, these emissions are referred to as 'indirect downstream scope 3 emissions'.

It is recognised that development of the Kyla field will contribute to overall volumes of GHG emissions in the atmosphere in combination with the other projects and activities emitting GHG emissions. The total gross GHG emissions generated over the life of the Kyla Field are estimated to be ca. 7,134.45 kilotonnes of CO_2e, based on the high production case (P10 profile). It should be noted, however, that there is only a 10% probability that recovered volumes will meet or exceed the P10 case estimate.

The total gross GHG emissions generated as a result of the proposed Kyla Development are considered to be compatible with global emissions reduction pathways and targets, including those set out by The Paris Agreement. The Paris Agreement is a legally binding international treaty adopted in 2015 that commits countries to limit global warming to under 2°C above pre-industrial levels and pursue efforts to keep it below 1.5°C.

The GHG emissions associated with the Kyla Development represent a very small fraction of projected global GHG emissions under the IPCC's low (SSP1-2.6) emissions pathway consistent with limiting warming to 2°C (ca. 0.00320% of median global GHG emissions in 2030). Kyla will also contribute a very small percentage towards predicted global oil and gas production rates in international pathways consistent with limiting warming to under 2°C (ca. 0.00602% in 2030 and ca. 0.00321% in 2035 of global oil production and ca. 0.00113% in 2030 and ca. 0.00059% in 2035 of global gas production). Of note, Kyla will cease production in or before 2038, well before the global target for Net Zero emissions by 2050. Development of the Kyla field is therefore not expected to materially affect the trajectory of global temperature rise or the achievement of international climate targets in a significant way.

In a national context, the GHG emissions associated with the Kyla Development represent only a small proportion of GHG emissions typically arising from oil and gas developments in the UKCS and will only contribute a small fraction of CO_2e emissions towards future UK carbon budget targets (ca. 0.28549% of Carbon Budget 5 and ca. 0.21826% of Carbon Budget 6) and the UK's NDC commitments (ca. 0.50692% of the 2030 NDC inventory target and ca. 0.41615% of the 2035 NDC inventory target). Given these non-significant proportions, the GHG emissions generated by the Kyla Development would have no material influence on the UK's ability to meet its Carbon Budget and NDC emissions reduction targets.

Notwithstanding the above, Serica is committed to minimising the amount of GHG emission produced, with the chosen development concept for Kyla representing one of the lowest carbon intensity increase means of recovering the remaining hydrocarbons in the Kyla field. During drilling and installation operations, vessel days and fuel consumption will be reduced, as far as practicable. Responsibility for identification and implementation of emissions reduction initiatives at Triton resides with the Triton FPSO operator (Dana). However, Serica (as the operator of Kyla) will support Dana as they continue to assess and implement reasonable decarbonisation strategies for Triton FPSO. Since the use of the

produced products is not within the control of Serica, no mitigation measures that could be taken by the Kyla Development to reduce Scope 3 downstream emissions are available to implement.

The UK Net Zero Growth Plan (DESNZ, 2023b) acknowledges that fossil fuels will retain a crucial role in the energy system until there are credible clean energy alternatives that can replicate their role. The Independent Review of Net Zero (Mission Zero, 2023) also recognises that in the short term the UK will still need oil and gas to secure our energy independence and as transition fuels towards 2050. In addition, the global demand for oil, particularly for use in petrochemical feedstocks and heavy transport, is forecast to persist through the energy transition period (IPCC, 2022; IEA, 2025). Furthermore, the UK is the second largest oil producer in Europe, a market with a massive oil supply deficit, meaning the UK is critical to Europe's integrated energy system exporting crude oil and importing refined oil products largely within the Northwest European market (OEUK, 2025c).

Over the life of the Kyla field, the Triton FPSO with the input of Kyla will have an average carbon intensity of 29.9 kg CO_2/boe in the unabated scenario, decreasing to 23.3 kgCO_2/boe if all projects identified in the Triton Emissions Reduction Action Plan are implemented. In comparison, the average carbon intensity for FPSOs in the CNS in 2024 was 30.5 kg CO_2/boe. When filtering by installation age (>25 years old) this increases to 37.5 kgCO_2/boe (NSTA, 2025b). The emissions intensity for UKCS offshore fields in 2024 was 24.0 kg CO_2/boe (NSTA, 2025a).

By operating within an already-licensed area (the previously decommissioned Kyle field) and maximising use of existing North Sea oil and gas infrastructure, Kyla contributes to maintaining secure domestic supply during the UK's broader energy transition while ensuring responsible stewardship of remaining offshore reserves.

Given the above, in a Paris Aligned oil and gas production pathway, the effect of the Kyla Development's GHG emissions on the global climate is therefore considered to be **Minor** and not significant.

14.5 Marine Discharges

No significant residual effects on water quality, plankton or fish are predicted as a result of routine marine discharges during the development of the Kyla development.

The main operational discharges into the marine environment from the proposed Kyla Development will occur as a result of the discharge of drill cuttings, muds and cement during drilling, the discharge of chemicals during drilling, hook-up and commissioning of subsea infrastructure, subsea intervention activities and decommissioning operations, as well as the incremental increase in produced water discharges at the Triton FPSO (host facility) as a result of Kyla coming online.

Upon release, these discharges will be subject to rapid dilution and dispersion and are not expected to persist within the marine environment. Additionally, a number of studies have shown that any impacts will be limited to the local area in the immediate vicinity of the discharge location and therefore no significant adverse residual effects are predicted.

Serica will implement a range of measures to mitigate any potential impacts including undertaking a chemical risk assessment to identify the risk profile of chemicals being used and / or discharged in accordance with the requirements of the Offshore Chemicals Regulations 2002 (as amended). Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile.

For assessment purposes, thermal cuttings treatment is being evaluated to treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% oil on cuttings). If not selected / considered to be feasible, the LTOBM contaminated cuttings would be skipped and shipped onshore for disposal.

During the production operations, any discharges of residual reservoir hydrocarbons in the produced water stream will be treated to meet oil in water limits of the Triton Oil Discharge Permit SAT. The discharge streams will also be monitored and sampled in accordance with the permit conditions.

Residual effects on water quality, plankton or fish from operational discharges into the marine environment from the proposed Kyla Development are therefore predicted to be **Minor** to **Negligible** are not significant.

Marine discharges from the proposed Kyla Development will occur within a region of established oil and gas activity, however, the closest neighbouring assets are located at sufficient distances such that cumulative effects on the wider marine environment are not anticipated.

14.6 Accidental Releases

All offshore activities associated with the Kyla Development will carry a potential risk of hydrocarbon pollution to sea; however, hydrocarbon spills from normal oil and gas operations are uncommon and can be effectively mitigated against. In planning its activities, Serica's primary focus is to ensure that all practicable measures are taken to prevent the occurrence of such accidental events and, should they occur, mitigate their effects. The consequences of an accidental release will vary depending on the quantity and type of hydrocarbon released, the wind speed and direction and sea state and the sensitivity of receptors depending on the time of year.

The worst-case spill scenario from the Kyla Development would be an uncontrolled and unmitigated subsea blowout scenario from the Kyla well, releasing ca. 867,861 m^3 of crude oil to the marine environment over 132 days (time taken to drill a relief well). Oil spill modelling has been conducted to determine the fate of Kyla hydrocarbons released from this worst case scenario. Given the proximity to the UK/Norway median line, located approximately 72 km east of Kyla, there is a 100% potential for a surface slick of oil to cross the median line in all seasons. Other median lines which could be crossed include Denmark (83% in winter), Germany (56% in winter), Sweden (54% in winter) and the Netherlands (41% in winter). The highest probability of shoreline oiling on the UK mainland is 39% in spring, with the shortest arrival time after 23 days in summer, although the risk of shoreline oiling is highest in Denmark in the winter (57%), with beaching occurring after 34 days. However, the Kyle crude is an ITOPF Group 2 (37.8° API) oil that undergoes rapid evaporation, dispersion and biodegradation upon release, and concentrations decline quickly following cessation of the blowout, and if this event were to occur, the oil is not predicted to persist in the water column, at the sea surface, or on the shoreline.

The risk of an accidental release occurring from the Kyla Development will be minimised through the implementation of physical barriers such as downhole safety valves, maintenance to minimise leaks, and the development and implementation of handling and operational procedures and training. Measures to respond to a spill from the MODU or the Kyla subsea facilities once operational will be covered in approved oil pollution emergency plans, which will be prepared in advance of drilling operations commencing offshore. As such, the overall risk to the marine environmental from an accidental release of hydrocarbons from the Kyla development is considered to range from **Medium** to **Low**, depending on the receptor impacted, but in all cases the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant.

Cumulative effects from accidental releases are not anticipated. As indicated by historical data, the likelihood of one major accidental release occurring is remote or extremely remote, limiting the cumulative impact from the Kyla Development and other existing installations.

14.7 Overall Conclusions

In summary, it is concluded that the proposed Kyla Development will not result in any significant environmental effects, including transboundary and cumulative effects.

15 References

Abbriano, R.M., Carranza, M.M., Hogle, S.L., Levin, R.A., Netburn, A.N., Seto, K.L., Snyder, S.M. and Franks, P.J.S. (2011) Deepwater Horizon oil spill: A review of the planktonic response. *Oceanography,* 24 (3): 294-301.

ABPmer Atlas of UK Marine Renewable Energy Resources (2008). Available from: http://www.renewables-atlas.info/ [Accessed September 2025].

Aires, C., González-Irusta, J.M. and Watret, R. (2014) Updating Fisheries Sensitivities Maps in British Waters. Scottish Marine and Freshwater Science Report. Vol. 5, No. 10. [Online] Available at: http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/fish-fisheries/fsm [Accessed September 2025].

Almeda, R., Wambaugh, Z., Wang, Z., Hyatt, C. Liu, Z. and Buskey, E.J. (2013). Interactions between zooplankton and crude oil: toxic effects and bioaccumulation of polycyclic aromatic hydrocarbons. PLoS ONE 8(6): e67212. Available at https://doi.org/10.1371/journal.pone.0067212

Auld, A.H. and Schubel, J.R. (1978) Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine, Coastal and Shelf Science, 6 (2): 153-164.

AUMS (1987) An Environmental Benthic Survey around Three North Sea Single Well Sites. Aberdeen University Marine Studies. Unpublished Report for the United Kingdom Offshore Operators Association (UKOOA).

Bakke, T., Klungsøyr, J., Sanni, S. (2013) Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. Marine Environmental Research. Vol. 92. 154-169

Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B. and Moffat, C.F. (eds) (2011) Scotland's Marine Atlas: Information for the National Marine Plan. Edinburgh: The Scottish Government. Available from: http://scotgov.publishingthefuture.info/publication/marine-atlas [Accessed December 2025]

BEIS (2017) *Environmental Information for Offshore Safety Directive Submissions – A Guide*. BEIS Offshore Environment Unit (OEU): Aberdeen.

BEIS (2019). The Climate Change Act 2008 (2050 Target Amendment) Order 2019 [Online]. Available from: https://www.legislation.gov.uk/ukdsi/2019/9780111187654 [Accessed November 2025].

BEIS (2021) North Sea Transition Deal. March 2021. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/972520/north-sea-transition-deal_A_FINAL.pdf [Accessed November 2025].

Bellas, J., Saco-Álvarez, L., Nieto, Ó., Bayona, J. M., Albaigés, J., and Beiras, R. (2013) Evaluation of artificially-weathered standard fuel oil toxicity by marine invertebrate embryo-genesis bioassays. *Chemosphere*, 90: 110.-1108.

BGS (2001) North Sea Geology – Technical Report 008 Rev1 – Geology [Online] Available from: https://assets.publishing.service.gov.uk/media/5a7a2a8340f0b66a2fc005f6/TR_SEA3_Geology.pdf [Accessed January 2026]

BGS (2015) Offshore marine information products – WMS. Available from: http://www.bgs.ac.uk/data/services/offprodwms.html [Accessed November 2025].

Black, K., & Parry, G., (1999) Entrainment, dispersal, and settlement of scallop dredge sediment plumes: Field measurements and numerical modelling. Canadian Journal of Fisheries and Aquatic Sciences. 56. 2271-2281.

Blix, A.S., Folkow, L.P. (1995) Daily energy expenditure in free living minke whales. Acta Physiologica Scandinavica: 153 (1). https://doi.org/10.1111/j.1748-1716.1995.tb09834.x

Bouloubassi, I., Fillaux, J. & Saliot, A. (2001) Hydrocarbons in Surface Sediments from the Changjiang (Yangtze River) Estuary, East China Sea. Marine Pollution Bulletin, pp.1335-46.

Breuer, E., Stevenson, A.G., Howe, J.A., Carroll, J., Shimmield, G.B. (2004) Drill cutting accumulations in the Northern and Central North Sea: a review of environmental interactions and chemical fate. Marine Pollution Bulletin. Vol. 48, 1-2. 12-25

BRIG (2011) Biodiversity Reporting and Information Group UK Biodiversity Action Plan: Priority Habitat Descriptions. Joint Nature Conservation Committee [JNCC]. https://hub.jncc.gov.uk/assets/2728792c-c8c6-4b8c-9ccd-a908cb0f1432

Brown, A.M., Majewska, K., Benhemma-Le Gall, A., Sinclair, R., Haber, I. & Ogilvy, C. (2025) Evidence review of harbour porpoise disturbance ranges in the context of the assessment and management of impulsive noise in Special Areas of Conservation: impact piling. JNCC Report 799, JNCC, Peterborough, ISSN 0963-8091. https://hub.jncc.gov.uk/assets/63e6edd9-2cc5-4011-b795-38c841bad198

Browne, N.K., Tay, J. and Todd, P.A. (2015) Recreating pulsed turbidity events to determine coral–sediment thresholds for active management, Journal of Experimental Marine Biology and Ecology, vol. 466, pp.98–109.

Bryan, G.W. and Langston, W.J. (1992) Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environmental Pollution, 76: 89-131.

Buchman, M.F. (2008) National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables. NOAA OR&R Report 08-1, Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, Seattle, 34 p.

Burnell, D., Perkins, A. J., Newton, S. F., Bolton, M., Tierney, T. D., & Dunn, T. E. (2023) Seabirds Count: a census of breeding seabirds in Britain and Ireland (2015–2021). Lynx Edicions, Barcelona.

Callaway, R., Alsvag, J., de Boois, I., Cotter, J., Ford, A., Hinz, H., Jennings, S., Kroncke, I., Lancaster, J., Piet, G., Prince, P. & Ehrich, S. (2002) Diversity and community structure of epibenthic invertebrates and fish in the North Sea. ICES Journal of Marine Science 59: 1199-1214.

Camphuysen, K.C.J., Chardine, J., Frederiksen, M. and Nunes, M. (2005) Review of the impacts of recent major oil spills on seabirds. In: Anonymous (ed.) *Report of the Working Group on Seabird Ecology*, 29 March - 1 April 2005, Texel, Netherlands. Copenhagen, Denmark: International Council for the Exploration of the Sea (ICES). Report No.: ICES CM 2005/C:05, Ref. ACME+E.

Carter, M.I.D., Boehme, L., Cronin, M.A., Duck, C.D., Grecian, W.J., Hastie, G.D., Jessopp, M., Matthiopoulos, J., McConnell, B.J., Miller, D.L., Morris, C.D., Moss, S.E.W., Thompson, D., Thompson, P.M., & Russell, D.J.F. (2022) Sympatric seals, satellite tracking and protected areas: habitat-based distribution estimates for conservation and management. Frontiers in Marine Science, Vol. 9, 875869.

Cefas (2001a) Contaminant status of the North Sea. Technical report produced for Strategic Environmental Assessment – SEA-2. Report No. TR_004. Available from: https://www.gov.uk/government/publications/strategic-environmental-assessment-2-supporting-documents [Accessed September 2025].

Cefas (2001b) Specifications for herring spawning ground surveys. Lowestoft: February 2001.

Cefas (2010) Spawning and Nursery Grounds Layers for Selected Fish in UK Waters in 2010. [Online] Available at: http://data.cefas.co.uk/#/View/153 [Accessed September 2025].

CIEEM (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine. Chartered Institute of Ecology and Environmental Management, Winchester.

Clark, C.W. (1990) Acoustic behavior of mysticete whales. In Sensory abilities of cetaceans. Springer, Boston, MA, 571-583.

Climate Change Committee (CCC) (2024). COP29: Key outcomes and next steps for the UK. [Online]. Available from: https://www.theccc.org.uk/publication/cop29-key-outcomes-and-next-steps-for-the-uk/ [Accessed October 2025]

Climate Change Committee (CCC) (2020) The Sixth Carbon Budget The UK's path to Net Zero. December 2020. [Online] Available from: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf [Accessed December 2025].

Climate Change Committee (CCC) (2025) The Seventh Carbon Budget. Advice for the UK Government. February 2025. [Online] Available from: https://www.theccc.org.uk/wp-content/uploads/2025/02/The-Seventh-Carbon-Budget.pdf [Accessed December 2025].

Climate Change Commission (CCC) (2025c) Progress-in-reducing-emissions-2024-Report-to-Parliament-Web. [Online]. Available from: https://www.theccc.org.uk/wp-content/uploads/2024/07/Progress-in-reducing-emissions-2024-Report-to-Parliament-Web.pdf [Accessed November 2025]

CNRI (2021). Banff & Kyla Decommissioning Project Environmental Appraisal. 90pp + appendices.

CONCAWE (2001) Report 01/54 Environmental classification of petroleum substances - summary data and rationale.

Cordes, E.E., Jones, D.O.B., Schlacher, T.A., Amon, D.J., Bernadino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Genio, L., Gobin, J., Henry, L.A., Herrera, S., Hoyt, S., Joye, M., Kark, S., Mestre, N.C., Metaxas, A., Pfeifer, S., Sink, K., Sweetman, A.K. and Witte, U., (2016). Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. *Frontiers in Environmental Science*, vol. 4, no. 58. DOI: 10.3389/fenvs.2016.00058.

Cormack, D., 1999. Response to marine oil pollution – review and assessment. Dordrecht, The Netherlands.

Coull, K.A., Johnstone, R. and Rogers, S.I. (1998) Fisheries Sensitivity Maps in British Waters. Aberdeen: UKOOA Ltd.

Cranmer, G J (1988) Environmental Survey of the Benthic Sediments Around Three Exploration Well Sites. Report 88/02, prepared for UKOOA by Aberdeen University Marine Studies Ltd.

Crown Estate Scotland (2025) The Crown Estate Scotland Spatial Hub. [Online] Available from: https://crown-estate-scotland-spatial-hub-coregis.hub.arcgis.com/ [Accessed September 2025].

Cummings, J.A. (2005) Operational multivariate ocean data assimilation. Quart. J. Royal Met. Soc., Part C, 131(613), 3583-3604

Cummings, J.A. and Smedstad., O. M. (2013) Variational Data Assimilation for the Global Ocean. Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications vol II, chapter 13, 303-343.

Daan, N. (2006). Spatial and temporal trends in species richness and abundance for the southerly and northerly components of the North Sea fish community separately, based on IBTS data 1977-2005. ICES CM 2006 D:02: 1-10.

Daan, R. and Mulder, M (1993) Long term effects of OBM cutting discharges at a drilling site on the Dutch Continental Shelf. NIOZ-report 1993-15, NIOZ, Texel, The Netherlands: 1-27

Dahl, P.H., de Jong C.A., Popper, A.N. (2015) The underwater sound field from impact pile driving and its potential effects on marine life. Acoustics Today, Spring 2015, Volume 11, Issue 2.

Dale, A.C., Boulcott, P., Sherwin, T.J. (2011) Sedimentation patterns caused by scallop dredging in a physically dynamic environment. Marine Pollution Bulletin. 62 (11). pp. 2433-2441

Danielssen, D.S., Edler, L., Fonselius, S.H., Hernroth, L., Ostrowski, M., Svendsen, E. and Talpsepp, L. (1997) Oceanographic variability in the Skagerrak and northern Kattegat, May–June 1990. ICES Journal of Marine Science, 54(5), pp.753–773.

De Robertis, A. and Handegard, N.O. (2013), Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review, ICES Journal of Marine Science, Volume 70, Issue 1, January 2013, Pages 34–45, https://doi.org/10.1093/icesjms/fss155.

DECC (2011) OESEA2 Environmental Report. Future Leasing/Licencing for Offshore Renewable Energy, Offshore Oil & Gas, Hydrocarbon Gas and Carbon Dioxide Storage and Associated Infrastructure. February 2011.

Dee, D.P., Uppala, S.M., Simmons, A.J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M.A., Balsamo, G., Bauer, D.P. and Bechtold, P. (2011). The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. Quarterly Journal of the royal meteorological society, 137(656), pp.553-597.

Defra (2010) Charting Progress 2. An assessment of the state of UK seas. Prepared by the UK Marine Monitoring and Assessment Strategy (UKMMAS) community, July 2010.

DEFRA (2024) United Kingdom Marine Monitoring & Assessment Strategy (UKMMAS) – Marine Mammals [Online] Available from: https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/marine-mammals/ [Accessed January 2026]

Delvigne, G.A.L., and C.E., Sweeney (1988) Natural dispersion of oil, Oil and Chemical Pollution 4:281-310.

Delvigne, G.A.L., and L.J.M., Hulsen (1994) Simplified laboratory measurement of oil dispersion coefficient – Application in computations of natural oil dispersion. Proceedings of the Seventeenth Arctic and Marine Oil Spill Program, Technical Seminar, June 8-10, 1994, Vancouver, British Columbia, Canada, pp. 173-187.

Dernie, K.M., Kaiser. M.J., Richardson, E.A. and Warwick, R.M. (2003) Recovery of soft sediment communities and habitats following physical disturbance. Journal of Experimental Marine Biology and Ecology, 285-286: 415-434.

DESNZ (2021) *The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 – A Guide*. July 2021. Available from: https://assets.publishing.service.gov.uk/media/60f961e68fa8f50429f0e6d1/The_Offshore_Oil_and_Gas_Exploration__Production__Unloading_and_Storage__Environmental_Impact_Assessment__Regulations_2020_-_A_Guide__July_2021.pdf [Accessed September 2025]

DESNZ and BEIS, 2022. North Sea Transition Deal. Updated: March 2022. [Online]. Available from: https://www.gov.uk/government/publications/north-sea-transition-deal [Accessed November 2025].

DESNZ (2022) UK Offshore Energy Strategic Environmental Assessment. Future Leasing/Licensing for Offshore Renewable Energy, Offshore Oil & Gas and Gas Storage and Associated Infrastructure. OESEA4 Environmental Report.

DESNZ (2023a). Carbon Budget Delivery Plan, March 2023. [Online]. Available from: https://assets.publishing.service.gov.uk/media/6424b2d760a35e000c0cb135/carbon-budget-delivery-plan.pdf [Accessed November 2025].

DESNZ (2023b). Powering Up Britain: Net Zero Growth Plan [Online]. Available from: https://www.gov.uk/government/publications/powering-up-britain/powering-up-britain-net-zero-growth-plan [Accessed November 2025].

DESNZ (2024a) Clean Power 2030 Action Plan: A new era of clean electricity. [Online] Available at: https://www.gov.uk/government/publications/clean-power-2030-action-plan [Accessed December 2025].

DESNZ (2024b). Statutory Security of Supply Report 2024. [Online]. Available at : https://www.gov.uk/government/publications/statutory-security-of-supply-report-2024/statutory-security-of-supply-report-2024 [Accessed December 2025].

DESNZ. (2025a). UK Greenhouse Gas Reporting Emission Factors. [Online]. Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2025 [Accessed December 2025].

DESNZ. (2025b). North Sea Future Plan for fair, managed and prosperous transition. [Online]. Available from: https://www.gov.uk/government/news/north-sea-future-plan-for-fair-managed-and-prosperous-transition [Accessed December 2025].

DESNZ (2025c) Environmental Impact Assessment (EIA) – Assessing effects of downstream scope 3 emissions on climate. Supplementary guidance for assessing the effects of downstream scope 3 emissions on climate from offshore oil and gas projects. June 2025. Available from:

https://assets.publishing.service.gov.uk/media/6853fa3d1203c00468ba2b15/Supplementary_guidance_-_Effects_of_Scope_3_Emissions.pdf [Accessed September 2025]

DOER (2000) Assessment of Potential Impacts of Dredging Operations Due to Sediment Resuspension. Massachusetts: Department of Energy Resources. [Online] Available from: http://www.dtic.mil/docs/citations/ADA377325 [Accessed November 2025].

Dooling, R.J. and Therrien, S.C. (2012) Hearing in Birds: What changes from air to water. In A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life. Pp. 77-82. Advances in Experimental Medicine and Biology 730, DOI 10.1007/978-1-4419-7311-5_17.

DOSITS (2017) Discovery of Sound in the Sea. Available from: http://www.dosits.org/ [Accessed November 2025].

DTI (2001) Strategic Environmental Assessment 2 (SEA 2). Department of Trade and Industry. Available from: https://www.gov.uk/government/consultations/strategic-environmental-assessment-2-sea-2 [Accessed November 2025].

DTI (2004) Strategic Environmental Assessment (SEA) 5: Environmental Report. [Online] Available from: https://www.gov.uk/government/publications/strategic-environmental-assessment-5-environmental-report [Accessed September 2025]

DTI (2005) *Strategic Environmental Assessment 5 (SEA 5)*. Department of Trade and Industry. Available from: https://www.gov.uk/government/consultations/strategic-environmental-assessment-5-sea-5 [Accessed December 2025].

Dyndo, M., Wisniewska, D.M., Rojano-Donate, L. & Madsen, P.T. (2015) Harbour porpoises react to low levels of high frequency vessel noise. Scientific Reports, 5: 11083.

Edds-Walton, P.L. (1997) Acoustic communication signals of mysticete whales. Bioacoustics, 8(1-2), 47-60.

Edwards, R. and White, I. (1999) *The Sea Empress Oil Spill: Environmental Impact and Recovery.* Paper presented at The International Oil Spill Conference 1999, 7-12 March 1999, Seattle, USA. Available from: http://www.itopf.com/knowledge-resources/documents-guides/document/the-sea-empress-oil-spill-environmental-impact-and-recovery-1999/ [Accessed December 2025].

EEMS (2008). EEMS Atmospheric Calculations. [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/136461/atmos-calcs.pdf [Accessed December 2025].

Ellis, J.R., Cruz-Martínez, A., Rackham, B.D. and Roger, S.I. (2004) The Distribution of Chondrichthyan Fishes around the British Isles and Implications for Conservation. Journal of Northwest Atlantic Fishery Science, 25: 195-213

Ellis, J.I., Fraser, G. & Russell, J. (2012a) Discharged drilling waste from oil and gas platforms and its effects on benthic communities. 456th ed. Marine Ecology Progress Series.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012b) Spawning and nursery grounds of selected fish species in UK waters. Lowestoft: Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Report No. 147.

Emissions Database for Global Atmospheric Research (EDGAR) (2025). Global Greenhouse Gas Emissions: EDGAR Community GHG Database, a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA), and comprising IEA-EDGAR CO2, EDGAR CH4, EDGAR N2O, EDGAR F-GASES version EDGAR_2025_GHG (2025) European Commission, JRC (Datasets) [Online]. Available from: https://edgar.jrc.ec.europa.eu/dataset_ghg2025 [Accessed October 2025]

EMODnet (2021) Seabed Habitats [Online] Available at: https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/ [Accessed September 2025]

EMODnet (2024) EMODnet Map Viewer [Online] Available from: https://emodnet.ec.europa.eu/geoviewer/ [Accessed September 2025]

Eno, N.C., MacDonald, D. & Amos, S.C. (1996) A study on the effects of fish (Crustacea/Molluscs) traps on benthic habitats and species. Final report to the European Commission. Study Contract, no. 94/076.

Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E., Embling, C.B. (2019) The effects of ship noise on marine mammals – a review. Frontiers in Marine Science, 6.

Erftemeijer, P.L.A., Riegl, B., Hoeksema, B.W. and Todd, P.A. (2012) Environmental impacts of dredging and other sediment disturbances on corals: A review, Marine Pollution Bulletin, vol. 64, pp. 1717–1765.

Etter, P.C. (1991). Underwater acoustic modelling: Principles, techniques and applications. Elsevier Science Publishers Ltd, Essex. ISBN 1-85166-528-5.

European Commission (EC) (2017) Environmental Impact Assessment of Projects Guidance on the Preparation of the Environmental Impact Assessment Report (Directive 2011/92/EU as amended by 2014/52/EU). European Union.

European Environment Agency [EEA]. (2022). EUNIS habitat type hierarchical view (marine version 2022 & terrestrial version 2021). https://eunis.eea.europa.eu/habitats-code-browser-revised.jsp?expand=30000,31361#level_31361

Fanneløp, T.K. and Sjøen, K. (1980) Hydrodynamics of underwater blowouts. AIAA 8th Aerospace Sciences Meeting, January 14-16, Pasadena, California. AIAA paper, pp. 80-0219.

FAO (2018) The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals. Food and Agriculture Organization of the United Nations, Rome.

Farrington, J.W. & Tripp, B.W. (1977) Hydrocarbons in western North Atlantic surface sediments. Geochimica et Cosmochimica Acta [PDF]. 41(11), pp.1627-41.

Feature Activity Sensitivity Tool (FeAST) (2025) [Online] Available from: https://feature-activity-sensitivity-tool.scot/ [Accessed November 2025]

Finneran, J.J., Schlundt, C.E., Carder, D.A., Clark, J.A., Young, J.A., Gaspin, J.B. and Ridgway, S.H. (2000) Auditory and behavioural response of bottlenose dolphins (Tursiops truncatus) and a beluga whale (Delphinapterus leucas) to impulsive sounds resembling distant signatures of underwater explosions. J. Acoust. Soc. Am. 108 (1): 417 – 431.

Fischer, R. (2000) Bow Thruster Induced Noise and Vibration. Paper presented at the Dynamic Positioning Conference, Houston, October 17 – 18, 2000.

Folk, R.L. (1954) The Distinction Between Grain size and Mineral Composition in Sedimentary Rock Nomenclature. Journal of Geology 62: 344-349.

Forster, P. et al., (2025). Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence. Supplement of Earth Syst. Sci. Data, 17, pp. 2641 – 2680. https://doi.org/10.5194/essd-17-2641-2025-supplement [Accessed October 2025]

Frederiksen, M., Wright, P.J., Harris, M.P., Mavor, R.A., Heubeck, M. and Wanless, S. (2006) Regional patterns of kittiwake Rissa tridactyla breeding success are related to variability in sandeel recruitment. Marine Ecology Progress Series, 300, 201-211.

French-McCay, D., Reich, D., Michel, J., Etkin, D., Symons, L., Helton, D., and J. Wagner. (2012) Oil Spill Consequence Analyses of Potentially-Polluting Shipwrecks. In Proceedings of the 34th AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada.

French-McCay, D., Reich, D., Rowe, J., Schroeder, M., and E., Graham. (2011) Oil Spill Modelling Input to the Offshore Environmental Cost Model (OECM) for USBOEMRE's Spill Risk and Cost Evaluations. In Proceedings of the 34th AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada.

French-McCay, D.P. (2002) Development and application of an oil toxicity and exposure model, OILTOXEX. Environmental Toxicology and Chemistry. 21(10): 2080-2094.

French-McCay, D.P. (2004) Oil spill impact modelling: Development and validation. Environmental Toxicology and Chemistry 23(10): 2441-2456.

Fugro (2017). Environmental Monitoring Report Bittern A and B. Fugro Document No.: 170020-09rev1. 99pp + appendices.

Fugro (2020) Characterisation and Environmental Surveys Banff and Kyle UKCS Blocks 22/27a and 29/2. Environmental Pre-Decommissioning Report. Edinburgh: Fugro GB Marine Limited.

Fugro (2020) Characterisation and Environmental Surveys Banff and Kyla UKCS Blocks 22/27a and 29/2. Environmental Pre-Decommissioning Report. Edinburgh: Fugro GB Marine Limited.

Fugro (2023). Bittern Environmental Seabed Survey. Environmental Monitoring Report. Report 230322-EDJ-021 U01, 80pp + appendices.

Gardline (2025a) Kyla Field Development Survey – Habitat Assessment Report. July 2025. Report No. 63748, Rev0.

Gardline (2025b) Kyla Field Development Environmental Survey – Environmental Baseline Survey. July 2025. Report No. 63748, Rev1.

Genesis (2011) Review and assessment of underwater sound produced by oil and gas activities and potential reporting requirements under the Marine Strategy Framework Directive. Aberdeen: Genesis Oil and Gas Consultants, Report No. J71656-Final Report-G2.

Genesis (2012) Fram Development. Assessment of sedimentation from pipelaying. Genesis Doc. No. J72242A-A-TN-00003.B2.

GESAMP (1993) *Impact of oil and related chemicals and wastes on the marine environment*. Joint Group of Experts on the Scientific Aspects of Marine Pollution. London: IMO. Reports No. 50.

GHG Protocol (2024). Corporate Standard. [Online]. Available from: https://ghgprotocol.org/corporate-standard#supporting-documents [Accessed November 2025].

Gilles, A, Authier, M, Ramirez-Martinez, NC, Araújo, H, Blanchard, A, Carlström, J, Eira, C, Dorémus, G, Fernández- Maldonado, C, Geelhoed, SCV, Kyhn, L, Laran, S, Nachtsheim, D, Panigada, S, Pigeault, R, Sequeira, M, Sveegaard, S, Taylor, NL, Owen, K, Saavedra, C, Vázquez-Bonales, JA, Unger, B, Hammond, PS (2023). Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final report published 29 September 2023. 64 pp. https://tinyurl.com/3ynt6swa

Global Carbon Project (GCP) (2024) Global Carbon Budget 2024 Presentation. Published on 13 November 2024. Available from: GCP_CarbonBudget_2024_slides_v1.0.pptx.pdf [Accessed July, 2025] 'Used with permission of the Global Carbon Project under the Creative Commons Attribution 4.0 International license'. [Accessed October 2025]

Goertner, J. F. (1978) Dynamical model for explosion injury to fish. Naval Surface Weapons Center, White Oak Lab, Silver Spring, MD. Report No. NSWC/WOL.TR-76-155.

Goertner, J. F., Wiley M L, Young G A, McDonald W W (1994) Effects of underwater explosions on fish without swim bladders. Naval Surface Warfare Center. Report No. NSWC/TR-76-155.

González, J., Figueiras, F.G., Aranguren-Gassis, M., Crespo, B., Fernández, E., Morán, X.A.G., Nieto-Cid, M. (2009). Effect of a simulated oil spill on natural assemblages of marine phytoplankton enclosed in microcosms. Estuarine, Coastal and Shelf Science. 83. 265-276. 10.1016/j.ecss.2009.04.001.

González-Irusta, J.M. and Wright, P.J. (2016) Spawning grounds of Atlantic cod (*Gadus morhua*) in the North Sea, ICES Journal of Marine Science, Volume 73, Issue 2, pp 304-315.

Gray, J. S., Aschan, M., Carr, M. R., Clarke, K. R., Green, T. H., Pearson, R., and Warwick, R. M. (1998) Analysis of community attributes of the benthic macro-fauna of Frierfjord-Langesundfjord and in a mesocosm experiment. *Marine Ecology Progress Series*, 46: 151-165.

Greenhouse Gas Protocol (GHGP) (2024). IPCC Global Warming Potential Values. [Online]. Available from: https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf [Accessed April 2025]

Gubbay, S. (2003) Marine aggregate extraction and biodiversity. Information, issues and gaps in understanding. Report to the Joint Marine Programme of the Wildlife Trusts and WWF-UK.

Halvorsen, M.B., Casper, B.C., Matthew, D., Carlson, T.J., and Popper, A.N. (2012) Effects of exposure to pile driving sounds on the lake sturgeon, Nila tilapia, and hogchoker. Proc. Roy. Soc. B, 279, 4705-4714.

Harper, Hugh & Sandwell, David. (2024). Global Predicted Bathymetry Using Neural Networks. Earth and Space Science. 11. 10.1029/2023EA003199.

Harrison, P.J., Cochlan, W.P., Acreman, J.C., Parsons, T.R., Thompson, P.A. and Dovey, H.M. (1986) The effects of crude oil and Corexit 9527 on marine phytoplankton in an experimental enclosure. *Marine Environmental Research*, 18: 93-109.

Hartley Anderson Ltd (2005) UKOOA Report to the Government/Industry Offshore Environmental Monitoring Committee 2004 Single Well Site Survey.

Hastie, G., Merchant, N.D., Götz, T., Russell, D.J.F., Thompson, P., Janik, V.M. (2019) Effects of impulsive noise on marine mammals: Investigating range-dependent risk.

Hawkins, A.D. (1993) Underwater Sound and Fish Behaviour IN: Pitcher, T.J. (ed.) Behavior of Teleost Fishes. London: Chapman & Hall: 129-169.

Hermannsen, L., Beedholm, K., Tougaard, J. and Madsen, P. T. (2014) High frequency components of ship noise in shallow water with a discussion of implications for harbour porpoises (Phocoena phocoena). J. Acoust. Soc. Am., 138, 1640–1653.

Highlands and Islands Enterprise (HIE) (2017) The Value of Aquaculture to Scotland. Inverness: HIE. Available at: https://cdn.prgloo.com/media/666bbb9760714718988ebcebc9d9b715 [Accessed October 2025].

Hill, J.M., Tyler-Walters, H. & Garrard, S.L. (2022) Seapens and burrowing megafauna in circalittoral fine mud. In Tyler-Walters H. Marine Life Information Network: Biology and Sensitivity Key Information Reviews. [Online] Available at: https://www.marlin.ac.uk/habitats/detail/131 [Accessed September 2025].

Hirata, K. (1999) Swimming speeds of some common fish. National Maritime Research Institute (Japan). Data sourced from Iwai T, Hisada M (1998). Fishes – Illustrated book of Gakken (in Japanese). Accessed on 8th March 2017 at http://www.nmri.go.jp/eng/khirata/fish/general/ speed/speede/htm.

HM Government (2008). Climate Change Act 2008. [Online]. Available from: https://www.legislation.gov.uk/ukpga/2008/27/contents [Accessed November 2025].

HM Government (2021). Net Zero Strategy: Build Back Greener. October 2021. [Online]. Available from: https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf [Accessed November 2025].

HM Government (2024) Final Statement for the Third Carbon Budget. [Online]. Available from: https://assets.publishing.service.gov.uk/media/664356ef4f29e1d07fadc6e9/third-carbon-budget-statement.pdf#:~:text=The%20UK%20met%20its%20first%20%282008-2012%29%20and%20second,2022%20with%20an%20emissions%20cap%20of%202%2C544%2C000%2C000%20tCO2e. [Accessed November 2025].

HM Government (2025) Carbon Budget and Growth Delivery Plan. Available from: https://assets.publishing.service.gov.uk/media/6901d0c2a6048928d3fc2b55/carbon-budget-and-growth-delivery-plan-report.pdf [Accessed December 2025].

Holland, Gayle & Greenstreet, Simon & Gibb, Iain & Fraser, Helen & Robertson, Michael. (2005) Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment. Marine Ecology-progress Series - MAR ECOL-PROGR SER. 303. 269-282. 10.3354/meps303269.

Howarth, M.J. (2001) Hydrography of the North Sea and adjacent regions. ICES Cooperative Research Report No. 248. International Council for the Exploration of the Sea (ICES), Copenhagen.

Hyland, J., D. Hardin, M. Steinhauer, D. Coats, D. R. Green, R., and J. Neff. (1994) Environmental impact of offshore oil development on the outer continental shelf and slope off Point Arguello, California. Mar. Environ. Res. 37:195-229.

Hyland, J., Balthis, L., Karakassis, I., Magni, P., Petrov, A., Shine, J., Vestergaard, O., Warwick, R. (2005) Organic carbon content of sediments as an indicator of stress in the marine benthos. Marine Ecology Progress Series. Vol. 295: 91-103

IAMMWG (2013) Management Units for Marine Mammals in UK waters (June 2013). Peterborough: Inter-Agency Marine Mammal Working Group, Joint Nature Conservation Committee.

IAMMWG (2022) Updated abundance estimates for cetacean Management Units in UK waters. JNCC Report No. 680 (Revised March 2022), JNCC Peterborough, ISSN 0963-8091.

ICES (2024) ICES-FishMap. Herring. [Online] Available at: https://www.ices.dk/about-ICES/projects/EURFP/EU%20Repository/ICES%20FIshMap/ICES%20FishMap%20species%20factsheeth erring.pdf#:~:text=The%20fish%20congregate%20on%20traditional%20spawning%20grounds%2C%2 0many,200%20m%29%20off%20the%20western%20coast%20of% [Accessed September 2025]

IEA (2018). The Future of Petrochemicals. [Online]. Available from: https://www.iea.org/reports/the-future-of-petrochemicals [Accessed November 2025].

IEA (2021). Net Zero by 2050: A Roadmap for the Global Energy Sector. Online]. Available from: https://www.iea.org/reports/net-zero-by-2050 [Accessed December 2025].

IEA (2023b). Energy Unit Converter. [Online]. Available from: https://www.iea.org/data-and-statistics/data-tools/unit-converter [Accessed December 2025].

IEA (2024). World Energy Outlook 2024. [Online]. Available from: https://www.iea.org/reports/world-energy-outlook-2024 [Accessed November 2025].

IEA (2025). World Energy Outlook 2025. [Online]. Available from: https://www.iea.org/reports/world-energy-outlook-2025 [Accessed December 2025].

IEMA (2016) Environmental Impact Assessment Guide to: Delivering Quality Development, July 2016. Institute of Environmental Management and Assessment.

IMO (2018) Adoption of the Initial IMO Strategy on Reduction of GHG Emissions from Ships and Existing IMO Activity Related to Reducing GHG Emissions in the Shipping Sector. London: IMO headquarters. Available from: https://unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April% 202018.pdf [Accessed April 2025].

Institution of Civil Engineers (IoCE). (2023). Guidance Document for Publicly Available Standard (PAS) 2080. [Online]. Available from: https://www.ice.org.uk/media/vm0nwehp/2023-03-29-pas_2080_guidance_document_april_2023.pdf [Accessed April 2025].

Intergovernmental Panel on Climate Change (IPCC) (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2 Energy. [Online]. Available from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html [Accessed December 2025].

Intergovernmental Panel on Climate Change (IPCC) (2019a). Special Report on Climate Change and Land / Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/report/srccl/ [Accessed October 2025].

Intergovernmental Panel on Climate Change (IPCC) (2019b). Special Report on the Ocean and Cryosphere in a Changing Climate / Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/srocc/home/ [Accessed October 2025].

Intergovernmental Panel on Climate Change (IPCC) (2020). The concept of risk in the IPCC Sixth Assessment Report: a summary of cross-Working Group discussion. [Online]. Available from: https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf [Accessed November 2025].

Intergovernmental Panel on Climate Change (IPCC) (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf [Accessed October 2025].

Intergovernmental Panel on Climate Change (IPCC) (2022). Sixth Assessment Report (AR6). Riahi, K., R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G.P. Peters, A. Rao, S. Robertson, A.M. Sebbit, J. Steinberger, M. Tavoni, D.P. van Vuuren, 2022: Mitigation pathways compatible with long-term goals. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.005 Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/assessment-report/ar6/ [Accessed April 2025].

Intergovernmental Panel on Climate Change (IPCC) (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647. Annex III Extended Data. [Online]. Available from: https://zenodo.org/records/5705391 [Accessed October 2025]

IOC-UNESCO. 2024. State of the Ocean Report. Paris, IOC-UNESCO. (IOC Technical Series, 190). https://doi.org/10.25607/4wbg-d349 [Accessed October 2025].

IOGP (2019) RISK ASSESSMENT DATA DIRECTORY Blowout Frequencies. September 2019. Report 434-02.

IPIECA-IOGP (2015) Impacts of oil spills on marine ecology. Good practice guidelines for incident management and emergency response personnel. IOGP Report 525.

Isaji, T., Howlett, E., Dalton, C., and Anderson, E. (2001) Stepwise-Continuous-Variable-Rectangular Grid Hydrodynamic Model, Environment Canada's 24th Arctic and Marine Oilspill (AMOP) Technical Seminar.

ITOPF (2014a) TIP 06: Recognition of oil on shorelines. Available at: https://www.itopf.org/knowledge-resources/documents-guides/document/tip-06-recognition-of-oil-on-shorelines/ [Accessed December 2025].

ITOPF (2014b) Technical Information Paper 13: Effects of Oil Pollution on the Marine Environment. London: The International Tanker Owners Pollution Federation Limited.

ITOPF (2014c) TIP 12: Effects of Oil Pollution on Social and Economic Activities. Available at: https://www.itopf.org/knowledge-resources/documents-guides/tip-12-effects-of-oil-pollution-on-social-and-economic-activities/ [Accessed April 2025].

ITOPF (2014d) Effects of Oil Pollution on Fisheries and Mariculture. Technical Information Paper 11, International Tanker Owners Pollution Federation, London.

IUCN (2025) The IUCN Red List of Threatened Species. [Online] Available at: https://www.iucnredlist.org/ [Accessed September 2025].

Jacobson, A.R. et al. (2023). CarbonTracker CT2022. Retrieved from NOAA Global Monitoring Laboratory: https://doi.org/10.25925/Z1GJ-3254

JNCC (2004) Developing regional seas for UK waters using biogeographic principles. Report by Joint Nature Conservation Committee to the Department for Environment, Food and Rural Affairs (DEFRA), 12 pp.

JNCC (2007) UK Biodiversity Action Plan – List of UK BAP Priority Marine Species (2007) [Online] Available from: https://jncc.gov.uk/resources/98fb6dab-13ae-470d-884b-7816afce42d4#UKBAP-priority-marine-species.pdf [Accessed November 2025]

JNCC (2010a) The Protection of Marine European Protected Species from Injury and Disturbance. Guidance for the Marine Area in England and Wales and the UK Offshore Marine Area. Peterborough: Joint Nature Conservation Committee (JNCC).

JNCC (2010b) Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise. Aberdeen: Joint Nature Conservation Committee (JNCC). Available from:

https://data.jncc.gov.uk/data/31662b6a-19ed-4918-9fab-8fbcff752046/JNCC-CNCB-Piling-protocol-August2010-Web.pdf [Accessed November 2025]

JNCC (2013) SACFOR abundance scale used for both littoral and sublittoral taxa from 1990 onwards. [pdf] Available at: https://mhc.jncc.gov.uk/media/1009/sacfor.pdf [Accessed September 2025]

JNCC (2014) Ocean Quahog *Arctica islandica* – Scottish MPA Project – Draft Fisheries Management Guidance [Online] Available from: https://jncc.gov.uk/resources/2d7638f7-cdd5-4153-8abb-9d33c5e02bf8 [Accessed November 2025]

JNCC (2019) At Sea Densities for Seabirds, by Season. [Shapefiles] Available from: https://data.gov.uk/search?filters%5Bformat%5D=&filters%5Bpublisher%5D=&filters%5Btopic%5D=&q=krigged [Accessed September 2025].

JNCC (2023) JNCC guidance for the use of Passive Acoustic Monitoring in UK waters for minimising the risk of injury to marine mammals from offshore activities. JNCC, Peterborough. https://hub.jncc.gov.uk/assets/fb7d345b-ec24-4c60-aba2-894e50375e33

JNCC (2023) Seabird Monitoring Programme Report 1986–2012. [Online] Available at: https://jncc.gov.uk/our-work/smp-report-1986-2022/ [Accessed September 2025]

JNCC (2024a) About Marine Protected Areas [Online] Available at: https://jncc.gov.uk/our-work/about-marine-protected-areas/ [Accessed September 2025]

JNCC (2024b) The East of Gannet and Montrose Fields MPA. [Online] Available from: https://jncc.gov.uk/our-work/east-of-gannet-and-montrose-fields-mpa/ [Accessed September 2025].

JNCC (2025) Updated Effective Deterrent Ranges (EDRs) for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise Special Areas of Conservation (SACs). (England, Wales & Northern Ireland) JNCC Report 803. JNCC, Peterborough, ISSN 0963-8091. https://hub.jncc.gov.uk/assets/5376c9a1-5d88-4291-aab4-028d5b4a1acd

Johansen, Ø., Brandvik, P.J., Leirvik, F., Farooq, U. & Daling, P. (2013) Oil droplet breakup and droplet size distributions in deep-water blowouts. Marine Pollution Bulletin, 73(1), pp.136–146.

Joint Research Council - Institute for Environment and Sustainability of the European Commission. (2010). ILCD Handbook [Online]. Available from: https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf [Accessed April 2025].

Jones, D.O.B., Gates, A.R. and Lausen, B., (2012). Recovery of deep-water megafaunal assemblages from hydrocarbon drilling disturbance in the Faroe-Shetland channel. *Marine Ecology Progress Series*, 461, pp. 71-82.

Jones, E.L., McConnell. B.J., Smout, S., Hammond, P.S., Duck, C.D., Morris, C.D., Thompson, D., Russell, D.J.F., Vincent, C., Cronin, M., Sharples, R.J. & Matthiopoulos, J. (2015) Patterns of space use in sympatric marine colonial predators reveal scales of spatial portioning. Marine Ecology Progress Series. 534: 235-249.

Joye, S.B., Bracco, A., Ozgokmen, T.M., Chanton, J.P., Grosell, M., MacDonald, I.R., Cordes, E.E., Montoya, J.P. and Passow, U. (2016) The Gulf of Mexico Ecosystem, six years after the Macondo Oil Well Blowout. Deep Sea Research Part II: Topical Studies in Oceanography. 129(1): 4–19. Available at: https://doi.org/10.1016/j.dsr2.2016.04.018

Kafas, A., Jones, G., Watret, R., Davies, I. and Scott, B. (2012) Representation of the use of marine space by commercial fisheries in Marine Spatial Planning. ICES Annual Science Conference, Bergen, Norway. International Council for the Exploration of the Sea, 1-2.

Kingston, P.F. (1992) Impact of offshore oil production installations on the benthos of the North Sea. ICES Journal of Marine Science, 49(1), pp.45-53.

Kinnear, J.A.M., Barkel, P.J., Mojseiwicz, W.R., Chapman, C.J., Holbrow, A.J., Barnes, C. & Greathead, C.F.F. (1996). Effects of Nephrops creels on the environment. Fisheries Research Services Report No. 2/96, 24 pp.

Kiørboe, T., Frantsen, E., Jensen, C. and Sørensen, G. (1981) Effects of suspended sediments on development and hatching of herring (Clupea harengus) eggs. Estuarine, Coastal and Shelf Science, 13 (1): 107-111.

Kirby, M.F., Brant, J., Moore, J., Lincoln, S., (eds) (2018) PREMIAM - Pollution Response in Emergencies - Marine Impact Assessment and Monitoring: Post-incident monitoring guidelines. Second Edition. Science Series Technical Report. Cefas, Lowestoft.

KIS-ORCA (2025) Interactive Map. [Online] Available from: https://kis-orca.org/map/ [Accessed September 2025].

Kjeilen-Eilertsen, G., Westerlund, S., Bamber, S., Tandber, A.H., Myhre, L.P. & Tvedten, O. (2004) UKOOA phase III- Characterisation of Beryl, Brent A, Brent S, Clyde and Miller cuttings piles through field work, laboratory studies and chemical analysis. Final Report – 2004-197.

Kober, K., Webb, A., Win, I., Lewis, M., O'Brien, S., Wilson, L.J. and Reid, J.B. (2010) An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs. JNCC report No. 431.

Kostylev, V.E. (2012) Benthic habitat mapping from seabed acoustic surveys: do implicit assumptions hold? In: Sediments, Morphology and Sedimentary Processes on Continental Shelves. Li, M.Z., Sherwood, C.R. and Hill, P.R. (Eds). International Association of Sedimentologists Special Publication ##, Blackwell Publishing Ltd, Oxford.

Krahn, M.M., G.M. Ylitalo, J. Buzitis, S. Chan, and U. Varanasi. (1993) Rapid High-performance Liquid Chromatographic Methods that Screen for Aromatic Compounds in Environmental Samples. *Journal of Chromatography*. Vol. 642, pp. 15-32.

Laist, D.W., Knowlton, A.R., Mead, J.G. Collet, A.S. & Podesta, M. (2001) Collisions between ships and whales. Marine Mammal Science, 17(1), pp.35-75.

Lan, X., Thoning, K.W., Dlugokencky, E.J. (2025). Trends in globally-averaged CO2, CH4, N2O, and SF6 determined from NOAA Global Monitoring Laboratory measurements. Version 2025-06. Retrieved from https://gml.noaa.gov/ccgg/trends/ [Accessed October 2025]

Lane, S.M., Smith, C.R., Mitchell, J., Balmer, B.C., Barry, K.P., McDonald, T., Mori, C.S., Rosel, P.E., Rowles, T.K., Speakman, T.R., Townsend, F.I., Tumlin, M.C., Wells, R.S., Zolman, E.S. and L.H. Schwacke (2015). Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisana, USA, following the Deepwater Horizon oil spill. Proceedings Royal Society B 282:1994-2001.

Langton, R., Boulcott, P. and Wright P.J. (2021) A verified distribution model for the lesser sandeel Ammodytes marinus. Marine Ecology Progress Series. https://doi.org/10.3354/meps13693

Latto P. L., Reach I.S., Alexander D., Armstrong S., Backstrom J., Beagley E., Murphy K., Piper R. and Seiderer L.J. (2013) Screening Spatial Interactions between Marine Aggregate Application Areas and Sandeel Habitat. A Method Statement produced for BMAPA.

Lee, R. F., and Page, D. S. (1997) Petroleum hydrocarbons and their effects in subtidal regions after major oil spills. *Marine Pollution Bulletin.* 34 (11): 928-940.

Leopold, M. & Camphuysen, K. (2009) Did the pile driving during the construction of the Offshore Wind Farm Egmond aan Zee, the Netherlands, impact local seabirds? IMARES – Wageningen UR, Report No. C062/07. Available at: https://tethys.pnnl.gov/publications/did-pile-driving-during-construction-offshore-wind-farm-egmond-aan-zee-netherlands-0

Lindsey, R. (2025). Climate Change: Atmospheric Carbon Dioxide. Retrieved from Climate.gov: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide [Accessed October 2025].

Løkkeborg, S., (2005). Impacts of trawling and scallop dredging on benthic habitats and communities. FAO Fisheries Technical Paper 472.

Long, E.R., MacDonald, D.D., Smith, S.L. & Calder, F.D. (1995) Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management. 19. pp.81-97.

Mackay, D., S. Paterson, and K. Trudel. (1980) A mathematical model of oil spill behaviour, Department of Chemical Engineering, University of Toronto, Canada, 39 pp.

Mackay, D., W. Shui, K. Houssain, W. Stiver, D. McCurdy, and S., Paterson. (1982) Development and calibration of an oil spill behavior model, Report No. CG-D027-83, US Coast Guard Research and Development Center, Groton, CT.

Mair, J.M., Matheson, I. & Appelbee, J.F. (1987) Offshore Macrobenthic Recovery in the Murchison Field Following the Termination of Drill-cuttings Discharges. Marine Pollution Bulletin, 18(12), pp.628-34.

Marine Scotland (2015) Scottish Sea Fisheries Statistics 2013 [Online] Available from: https://www.gov.scot/publications/scottish-sea-fisheries-statistics-2015-9781786524300/ [Accessed November 2025]

Marine Scotland (2020) Scotland's Marine Assessment 2020: Aquaculture. Edinburgh: Scottish Government. Available at: https://marine.gov.scot/sma/assessment/aquaculture [Accessed October 2025].

Marine Scotland (2021) Scottish Sea Fisheries Statistics 2020 [Online] Available from: https://www.gov.scot/publications/scottish-sea-fisheries-statistics-2020/ [Accessed November 2025]

MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd & Marine Ecological Surveys Ltd (2013) Environmental Effect Pathways between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat: Regional Cumulative Impact Assessments. Version 1.0. A report for the British Marine Aggregates Producers Association.

Mason, T. (2013) Modelling of Subsea Noise During the Proposed Piling Operations at the Dudgeon Wind Farm. Report submitted to Royal Haskoning DHV. Bishop's Waltham: Subacoustech Environmental Ltd. Report Ref: E438R0106.

McCauley, R. D. (1994) "Seismic surveys" in Environmental Implications of Offshore Oil and Gas Development in Australia – The Findings of an Independent Scientific Review, edited by J. M. Swan, J. M. Neff, and P. C. Young. Australian Petroleum Exploration Association, Sydney, pp. 19–122.

McConnell BJ, Fedak MA, Lovell P & Hammond PS (1999). Movements and foraging of grey seals in the North Sea. Journal of Applied Ecology 36: 573-590.

McDougall, J. (2000) Section 5.1. The significance of hydrocarbons in surficial sediments from the Atlantic Margin regions. In Hydrocarbons in environmental surveys of the seafloor of the UK Atlantic Margin. Daventry, Northants NN11 5EA, UK.: Geotek Limited ISBN 09538399-0-7.

McDougall, T.J. (1978) Bubble plumes in stratified environments. Journal of Fluid Mechanics 85(4): 655-672.

McLeese, D. W., Sprague, J. B., and Ray, S. (1987) Effects of cadmium on marine biota. p. 171-198. In: Nriagu, J.O. and J.B. Sprague (eds.). Cadmium in the Aquatic Environment. Advances in Environmental Science and Technology, Volume 19. John Wiley & Sons, New York. 272 pp.

Met Office (2025). Climate Dashboard. Retrieved from Met Office: https://climate.metoffice.cloud/ [Accessed October 2025].

Mission Zero (2023). Independent Review of Net Zero. January 2023. [Online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1128689/mission-zero-independent-review.pdf [Accessed December 2025]. Forster, P. et al (2024) Indicators of Global Climate Change 2023: annual update of key indicators of the state of the climate system and human influence. Earth Syst. Sci. https://doi.org/10.5194/essd-16-2625-2024

Morris, C.D., Duck, C.D. and Thompson, D. (2021). Aerial surveys of seals in Scotland during the harbour seal moult, 2016-2019. NatureScot Research Report 1256.

Moyle, P.B. and Cech, J.J. (2004) Fish: an introduction to ichthyology, 3rd ed. Cloth: Pearson.

Munk, W.H. and Zachariasen (1991) Refraction of sound by islands and seamounts. Journal of Atmospheric and Oceanic Technology. 8(4), pp.554-574.

Murawski, S. A., Hogarth, W.T., Peebles, E.B and Barbeiri, L. (2014) 'Prevalence of External Skin Lesions and Polycyclic Aromatic Hydrocarbon Concentrations in Gulf of Mexico Fishes, Post-Deepwater Horizon'. Transactions of the American Fisheries Society. 143(4)

Myrberg, A.A. (2001) The acoustical biology of elasmobranchs. Environmental Biology of Fishes. 60: 31 – 45.

National Marine Fisheries Service (NMFS) (2018). 2018 Revisions to: Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum, NMFS-OPR-59. Available from: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance [Accessed November 2025].

National Research Council (NRC) (1983) Drilling discharges in the marine environment. Washington DC: National Academy. p1–180.

Nature Scot (2022) List of Nature Scot Priority Marine features. Available online at: https://www.nature.scot/sites/default/files/2020-10/Priority%20Marine%20Features%20in%20Scotlands%20seas.pdf [Accessed September 2025].

Nature Scot (2022) List of Nature Scot Priority Marine features. Available online at: https://www.nature.scot/sites/default/files/2020-10/Priority%20Marine%20Features%20in%20Scotlands%20seas.pdf [Accessed November 2025].

Neal, K.J. & Avant, P. (2008) Owenia fusiformis A tubeworm. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [online]. Plymouth: Marine Biological Association of the United Kingdom. Available from: https://www.marlin.ac.uk/species/detail/1703 [Accessed November 2025].

Neff J.M., Hillman R.E. and Waugh J.J (1989) Bioaccumulation of trace metals from drilling mud barite by benthic animals. In Engelhardt F.R., Ray J.P. & Gillam A.H. (eds.) Drilling Wastes. Proceedings of the 1988 International Conference on Drilling Wastes, Calgary, Alberta, Canada, 461 to 479.

Neff, J.M. (1982) Fate and Biological Effects of Oil Well Drilling Fluids in the Marine Environment: A Literature Review. EPA-600/S3-82-064). Report to U.S. Environmental Protection Agency, Gulf Breeze, FL. 151 pp.

Neff, J.M. (1990). Composition and fate of petroleum and spill-treating agents in the marine environment. In: Sea Mammals and Oil: Confronting the risks. Geraci, J.R. and St. Aubin, D.J. (eds.) San Diego: Academic Press.

Neff, J.M. (2004) Bioaccumulation in Marine Organisms: Effect of Contaminants from Oil Well Produced Water. Oxford, UK: Elsevier.

Neff, J.M. (2005) Composition, Environmental Fates, and Biological Effects of Water Based Drilling Muds and Cuttings Discharged to the Marine Environment: A synthesis and annotated bibliography. PERF report prepared by Battelle Ltd.

Neilson, J. L., Gabriele, C.M., Jensen, A. S., Jackson, K., and Straley, J.M. 2012. Summary of reported whale-vessel collisions in Alaskan waters. Journal of Marine Biology, 2012: 18.

National Energy System Operator (NESO) (2025) Gas Supply Security Assessment. Assessing gas supply security five and ten years ahead. November 2025. [Online]. Available from: https://www.neso.energy/document/372661/download [Accessed January 2026]

NMPi (2025) National Marine Plan Interactive. [Online] Available from: https://marinescotland.atkinsgeospatial.com/nmpi/ [Accessed September 2025].

NSTA (2021) *NSTA Net-Zero Asset Stewardship Expectation 11.* March 2021. Available from: https://www.nstauthority.co.uk/media/7184/se11_net-zero.pdf [Accessed November 2025]

NSTA (2024a) *OGA Plan to reduce UKCS greenhouse gas emissions*. March 2024. Available from: https://www.nstauthority.co.uk/regulatory-information/regulatory-framework/the-oga-strategy/oga-plan-emissions-reduction/ [Accessed September 2025]

NSTA (2024b) Emissions Monitoring Report 2024. [Online]. Available from: https://www.nstauthority.co.uk/media/nugh4i0q/emissions-monitoring-report-2024.pdf [Accessed April 2025].

NSTA (2025a) Emissions Monitoring Report 2025. [Online]. Available from: https://www.nstauthority.co.uk/news-publications/emissions-monitoring-report-2025/ [Accessed November 2025].

NSTA (2025b) UKCS Emissions Monitoring Dashboard 2025. UKCS Offshore GHG Benchmarking. [Online] Available from: https://app.powerbi.com/view?r=eyJrIjoiOTYzNmVhYWEtNmNjYy00Zjg2LWIwNGQtMGUyNDI3NjY5N2VhIiwidCI6ImU2ODFjNTlkLTg2OGUtNDg4Ny04MGZhLWNlMzZmMWYyMWIwZiJ9 [Accessed November 2025].

NSTA (2025c) North Sea Transition Authority Open Data [Online] Available at: https://opendata-nstauthority.hub.arcgis.com/search [Accessed September 2025].

NSTA (2025d) *NSTA Overview 2025*. Available from: https://www.nstauthority.co.uk/news-publications/nsta-overview-2025/ [Accessed September 2025]

OEUK (2024a). Emissions Reduction Report 2024. [Online]. Available from: https://oeuk.org.uk/product/emissions-reduction-report-2024/ [Accessed April 2025].

OEUK (2024b) ENVIRONMENTAL INSIGHT. September 2024. Offshore Energies UK. Available from: https://oeuk.org.uk/wp-content/uploads/2024/09/Environmental-Insight-September-2024-Offshore-Energies-UK-OEUK.pdf.

OEUK (2025a) Environmental Insight 2025 [Online] Available from: https://oeuk.org.uk/wp-content/uploads/woocommerce_uploads/2025/09/Environment-Insight-Report-2025-Final-bqvql2.pdf [Accessed December 2025].

OEUK (2025b). OEUK Business Outlook 2025. [Online]. Available from: https://oeuk.org.uk/product/business-outlook-report-2025/ [Accessed December 2025].

OEUK (2025c). New Wood Mackenzie Report shows Critical Role of UK Oil for Europe's Integrated Energy System [Online]. Available from: https://oeuk.org.uk/new-wood-mackenzie-report-shows-critical-role-of-uk-oil-for-europes-integrated-energy-system/?dm_i=68Y3,1ALJC,NINT9,60U3U,1 [Accessed December 2025].

OGA (2016) 29th Licensing Round Information – Levels of Shipping Activity. Available from: https://www.ogauthority.co.uk/media/2213/other_regulatory_issues-230816.pdf [Accessed September 2025].

OGA (2019) 32nd Licencing Round Information – Other Regulatory Issues. (Version dated 11th July 2019).

OGA (2020) The OGA Strategy. December 2020. Available from: https://www.ogauthority.co.uk/media/7105/the-oga-strategy.pdf [Accessed November 2025].

OGP (2005) Fate and effects of naturally occurring substances in produced water on the marine environment. Report No. 364.

OGP (2010) Risk Assessment Data Directory – Major Accidents. London: International Association of Oil & Gas Producers. Report No. 434-17. Available at: http://www.ogp.org.uk/pubs/434-17.pdf [Accessed December 2025].

OGUK (2014) Environment Report 2014, Oil & Gas UK.

OGUK (2019) Environment Report 2018, Oil & Gas UK (OGUK).

OPRED (2022) UK Offshore Energy Strategic Environmental Assessment. Future Leasing/Licensing for Offshore Renewable Energy, Offshore Oil & Gas and Gas Storage and Associated Infrastructure. OESEA4 Environmental Report. March 2022.

OPRED (2025). EIA – Assessing effects of downstream scope 3 emissions on climate - Supplementary guidance. June 2025.

Oslo and Paris Commission (OSPAR) (2010). Background document for sea pens and burrowing megafauna. OSPAR Commission biodiversity series (Publication Number: 481/2010). OSPAR Commission. Available from : https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats [Accessed November 2025]

OSPAR (2008) OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR Reference Number: 2008-6). [Online] Available at: https://www.ospar.org/site/assets/files/1505/08-06e_ospar_list_species_and_habitats.doc [Accessed September 2025].

OSPAR (2009) Overview of Impact of anthropogenic underwater sound in the marine environment. Biodiversity Series. London: OSPAR Commission. Available from: http://qsr2010.ospar.org/media/assessments/p00441_Noise_background_document.pdf [Accessed November 2025].

OSPAR (2010) Background Document for Seapen and Burrowing megafauna Communities. [pdf] Available at: https://www.ospar.org/documents?v=7261 [Accessed September 2025].

OSPAR (2014) Agreement 2014-05. Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water.

OSPAR (2024) OSPAR Commission List of Threatened and / or Declining Species and Habitats. Available at: http://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats [Accessed September 2025].

Otani, S., Naito, Y., Kato, A. and Kawamura, A. (2000) Diving behaviour and swimming speed for free-ranging harbour porpoise, *Phocoena phocoena*. MARINE MAMMAL SCIENCE, 6(4):811-814.

Ozhan, K., Parsons, M.L. and Bargu, S. (2014). How were phytoplankton affected by the Deepwater Horizon oil spill? Bioscience. 64(9): 829–836.

Palka, D.L., Hammond, P.S. (2001) Accounting for responsive movement in like transect estimates of abundance. Canadian Journals of Fisheries and Aquatic Sciences, 58.

PARLOC (2012) Pipeline and Rise Loss of Containment 2001 – 2012 (PARLOC, 2012). PARLOC Report Series, London: Energy Institute and Oil & Gas UK, March 2015, 6th Edition.

PARLOC (2024) Pipeline and riser loss of containment 2001 – 2020 (PARLOC 2020). 7th edition.

Perez, M., Munilla, I., López-Alonso, M. and Velando, A. (2009) Sub-lethal effects on seabirds after the Prestige oil-spill are mirrored in sexual signals. *Biology Letters,* 6: 33-35.

Pidduck, E., Jones, R., Daglish, P., Farley, A., Morley, N., Page, A. and Soubies, H., (2017). *Identifying the possible impacts of rock dump from oil and gas decommissioning on Annex I mobile sandbanks.* JNCC Report No. 603. JNCC, Peterborough.

Pomeroy, P. P., Worthington Wilmer, J., Amos, W., Twiss, S. D. (2000) Reproductive Performance Links To Fine Scale Spatial Patterns Of Female Grey Seal Relatedness. Sea Mammal Research Unit, Scotland, UK.

Popper, A.N. (2012) Laboratory of Aquatic Bioacoustics. Available from: http://www.life.umd.edu/biology/popperlab/ [Accessed November 2025].

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., Halvorsen, M.B., Løkkeborg, S., Rogers, P.H., Southall, B.L., Zeddies, D.G. and Tavolga, W.N. (2014) Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report Prepared by ANSI Accredited Standards Committee S3/SC1 and registered with ANSI. Cham, Switzerland: Springer and ASA Press.

Production Gap Report (PGR). (2023). The Production Gap Report 2023: Phasing down or phasing up? Top fossil fuel producers plan even more extraction despite climate promises. [Online]. Available from: https://www.sei.org/publications/production-gap-report-2023/ [Accessed December 2025].

Production Gap Report (PGR). (2025). 2025 Report. [Online]. Available from: https://productiongap.org/2025report/#2025downloads [Accessed December 2025].

Reach I.S., Latto P., Alexander D., Armstrong S., Backstrom J., Beagley E., Murphy K., Piper R. and Seiderer L.J. (2013) Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Areas. A Method Statement produced for BMAPA.

Reed, M., E. Gundlach, and T. Kana, (1989) A coastal zone oil spill model: development and sensitivity studies, Oil and Chemical Pollution 5:411-449.

Reid, J. B., Evans, P. G. H. and Northridge, S. P. (2003) Atlas of Cetacean distribution in north-west European waters. Peterborough: Joint Nature Conservation Committee (JNCC).

Reiss, H., Degraer, S., Duineveld, G.C.A., Kröncke, I., Aldridge, J., Craeymeersch, J.A., Eggleton, J.D., Hillewaert, H., Lavaleye, M.S.S., Moll, A., Pohlmann, T., Rachor, E., Robertson, M., Vanden Berghe, E., van Hoey, G. & Rees, H.L. (2010). Spatial patterns of infauna, epifauna and demersal fish communities in the North Sea. ICES Journal of Marine Science 67: 278-293.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I. and Thomson, D.H. (1995) Marine Mammals and Noise. San Diego: Academic Press.

Robinson, S.P., Lepper, P.A., and Hazelwood, R.A. (2014) Good practice guide for underwater noise measurement. National Measurement Office, Marine Scotland, The Crown Estate. NPL Good Practice Guide No. 133, ISSN: 1368-6550.

Rodhe, J. (1996) On the dynamics of the large-scale circulation in the Skagerrak. Journal of Sea Research, 35(1–3), pp.9–21.

Rogers, C.S. (1990) Reponses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series, 62, 185 – 202.

Rolland, R.M., Parks, S.E., Hunt, K.E., Castellote, M., Corkeron, P.J., Nowacek, D.P., Wasser, S.K. & Kraus, S.D. (2012) Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B 279: 2363-2368.

Rouse, S., Hayes, P. and Wilding, T.A., (2020). Commercial fisheries losses arising from interactions with offshore pipelines and other oil and gas infrastructure and activities. ICES Journal of Marine Science, 77,1148-1156.

RPS (2025) Serica Energy – Kyla Well – Drill Cuttings and Muds Dispersion Modelling. GOC425786. December 2025.

RPS (2025) SERICA ENERGY – KYLA WELL, Drill Cuttings and Muds Dispersion Modelling – Rev 2. GOC425786. 5 December 2025.

RSPB (2025) Birds and Wildlife. Available from: https://www.rspb.org.uk/birds-and-wildlife [Accessed September 2025]

Rust, A.J., Burgess, R.M., Brownawell, B.J. and McElroy, A.E. (2004) Relationship between metabolism and bioaccumulation of benzo[a]pyrene in benthic invertebrates. Environmental Toxicology and Chemistry. 23 (11): 2587 – 2593.

SCOS (2005) Scientific advice on matters related to the management of seal populations: 2014. Special Committee on Seals. Available from: https://www.smru.st-andrews.ac.uk/research-policy/scos/ [Accessed September 2025].

SCOS (2014) Scientific advice on matters related to the management of seal populations: 2014. Special Committee on Seals. Available from: https://www.smru.st-andrews.ac.uk/research-policy/scos/ [Accessed September 2025].

SCOS (2024). Scientific advice on matters related to the management of seal populations: 2024. Natural Environment Research Council Special Committee on Seals. Available from: https://www.smru.st-andrews.ac.uk/research-policy/scos/ [Accessed September 2025].

Scottish Government (2017) Guidance on applying a waste hierarchy under Section 34 of the Environmental Protection Act 1990. Published 29 November 2017. Available from: https://www.gov.scot/publications/guidance-applying-waste-hierarchy/documents/ [Accessed July 2025]

Scottish Government (2023) Our Aquaculture. Edinburgh: Scottish Government. Available at: https://aquaculture.scotland.gov.uk/OurAquaculture [Accessed October 2025].

Scottish Natural Heritage (2016) NatureScot Commissioned Report 406: Descriptions of Scottish Priority Marine Features (PMFs). [PDF] Scottish Natural Heritage Available at: https://www.nature.scot/sites/default/files/Publication%202016%20-%20SNH%20Commissioned%20Report%20406%20-%20Descriptions%20of%20Scottish%20Priority%20Marine%20Features%20%28PMFs%29.pdf [Accessed September 2025]

Serica (2025) Redevelopment of the former Kyle Field, proposed to be renamed the Kylie Field Concept Select Report. Serica Energy Chinook Ltd. Report: KYL-SECL-ENG-REP-0001.

Seuront, L. (2010) *Fractals and Multifractals in Ecology and Aquatic Science.* Florida, USA: CRC Press.

Scottish Government's Marine Directive (SG-MD) (2025) Fishing Effort and Quantity and Value of Landings by ICES Rectangle. [Online] Available at: https://www.gov.scot/collections/sea-fisheries-statistics/ [Accessed January 2026].

SINTEF (2014) Intercomparison of oil spill prediction models for accidental blowout scenarios with and without subsea chemical dispersant injection. SINTEF Report No. A26328, SINTEF Ocean, Trondheim, Norway.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C. and Popper, A. N. (2010) A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution, 25: 419-427.

Smit, M.G.D., Bechmann, R.K., Hendriks, A.J., Skadsheim, A., Larsen, B.K., Baussant, T., Sanni, S. (2009) Relating effect levels to whole-organism effects using species sensitivity distributions: A pilot study for marine species exposed to oil. Environmental Toxicology and Chemistry 28(5):1104-9.

SNH and HES (2018) Environmental Impact Assessment Handbook - Guidance for competent authorities, consultation bodies, and others involved in the Environmental Impact Assessment process in Scotland. Version 5, April 2018. Scottish Natural Heritage and Historic Environment Scotland.

Southall, B.L. (2021). Evolutions in Marine Mammal Noise Exposure Criteria. Acoustics Today 17(2) https://doi.org/10.1121/AT.2021.17.2.52.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. and Tyack, P.L. (2007) Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals, 33: 411–521.

Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., and Tyack, P.L., (2019) Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals, 45(2), 125-232

Spaulding, M., Li, Z., Mendelsohn, D., Crowley, D., French-McCay, D. & Bird, A. (2017) Application of an integrated blowout model system (OILMAP Deep) to the Deepwater Horizon spill. Marine Pollution Bulletin, 120(1–2), pp.37–50.

Spaulding, M.L. (1982) User's manual for a simple gas blowout plume model. Continental Shelf Institute, Trondheim, Norway.

Stein, J.E., Oliver, J.E. and Schwaab, E.C. (2010) Metabolism of PAHs by teleost fish, scientific findings Memorandum to Eric Schwaab, Assisstant Administrator for Fisheries, National Marine Fisheries Service and John Oliver, Deputy Assisstant Administrator for Operations, National Marine Fisheries Service, from /s/ John E. Stein, Deputy Director Northwest Fisheries Science Center, NMFS. [Online] Available at: https://repository.library.noaa.gov/view/noaa/114 [Accessed December 2025].

Stephenson, J. R., Gingerich, A.J., Brown, R.S., Pflugrath, B.D., Deng, Z., Carlson, T.J., Langeslay, M.J., Ahmann, M.L., Johnson, R.L., Seaburg, A.G. (2010) Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory. Fisheries Research, Volume 106, Issue 3, pp 271-278.

Stump, R., Kettle, B., Campbell, D., Zarillo, G. and Shay, N. (2019) White Paper on Biological Thresholds for Adaptive Dredge Management, Report to United States Army Corps of Engineers, South Atlantic Division, Jacksonville District.

Subacoustech (2025) Subsea Piling in the Kyla Oil Field (UKCS Block 29/2c): Underwater Noise Modelling Assessment. 31st October 2025. Report No. P435R0101

Suchanek, T.H., (1993) Oil impacts on marine invertebrate populations and communities. *American Zoologist,* 33, 510-523.

Takeshita, R., Sullivan, L., Smith, C., Collier, T., Hall, A., Brosnan, T., Rowles, T., Schwacke, L. (2017) The Deepwater Horizon oil spill marine mammal injury assessment. Endangered Species Research, 33, 95-106

Taylor, A.C. (1976). Burrowing behaviour and anaerobiosis in the bivalve *Arctica islandica*. Journal of the Marine Biological Association, 56:95-109.

Tillin, H. & Tyler-Walters, H., (2014). Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. JNCC Report No. 512B, 260 pp. Available from https://www.marlin.ac.uk/publications

Tillin, H.M., Hull, S.C. & Tyler-Walters, H. (2010). Development of a sensitivity matrix (pressures-MCZ/MPA features). Report to the Department of the Environment, Food and Rural Affairs from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. Defra Contract no. MB0102 Task 3A, Report no. 22. London, 145 pp.

Tozer, B, Sandwell, D. T., Smith, W. H. F., Olson, C., Beale, J. R., & Wessel, P. (2019) Global bathymetry and topography at 15 arc sec: SRTM15+. Earth and Space Science. 6.

Tremlett, C. J., Morley, N., & Wilson, L. J. (2024) UK Seabird Colony Counts in 2023 Following the 2021/22 Outbreak of Highly Pathogenic Avian Influenza. RSPB Research Report 76. RSPB, Sandy.

Trudel, B.K., R.C. Belore, B.J. Jessiman and S.L., Ross. (1989) A Mico-computer Based Spill Impact Assessment System for Untreated and Chemically Dispersed Oil Spills in the U.S. Gulf of Mexico. 1989 International Oil Spill Conference.

Tuck, I.D., Hall, S.J., Robertson, M.R., Armstrong, E. & Basford, D.J. (1998) Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. Marine Ecology Progress Series, 162, 227-242.

Turnpenny, W. H. and Nedwell J. R. (1994) The Effects on Marine Fish, Diving Mammals and Birds of Underwater Sound Generated by Seismic Surveys. Southampton: Fawley Aquatic Research Laboratories Ltd / Subacoustech Ltd.

Tuvikene, A. (1995) Responses of fish to polycyclic aromatic hydrocarbons (PAHs). Annales Zooligici Fennici. 32 (3): 295-309.

Tyack, P. L. and Clark, C.W. (2000) Communication and acoustic behavior of dolphins and whales. In Hearing by whales and dolphins. Springer New York, pp.156-224.

Tyler-Walters, H., James, B., Carruthers, M., Wilding, C., Durkin, O., Lacey, C., Philpott, E., Adams, L., Chaniotis, P.D., Seeley, P.T.V., Neilly, M., Dargie, J. & Crawford-Avis, O.T. (2016) Descriptions of Scottish Priority Marine Features (PMFs). Scottish Natural Heritage Commissioned Report No. 406. Inverness, UK: NatureScot Marine Scotant.

UK Government (2025). United Kingdom of Great Britain and Northern Ireland's 2035 Nationally Determined Contribution Presented to Parliament by the Secretary of State for Energy Security and Ne Zero by Command of His Majesty January 2025. 74 pp. [Online]. Available from: https://unfccc.int/sites/default/files/2025-01/UK%27s%202035%20NDC%20ICTU.pdf [Accessed November 2025].

UKHO (2024) ADMIRALITY Marine Data Portal [Online] Available at: https://datahub.admiralty.co.uk/portal/apps/sites/?_gl=1*1j24oc6*_ga*MjY0MTE4NjAxLjE2ODg3ND

QwODg.*_ga_8PTW8GJL1R*MTY5MjExMDgzMC44LjAuMTY5MjExMDgzMC4wLjAuMA..#/marine-data-portal/items/c5afebefad5c49008b8ffc36523a953a [Accessed September 2025]

UKHO (UK Hydrographic Office) (2013) North Sea (West) Pilot: East coasts of Scotland and England from Rattray Head to Southwold. 9th edition. The Hydrographer of the Navy, UK 232pp.

UKOOA (2001) An analysis of U.K Offshore Oil & gas Environmental Surveys 1975-95, pp. 141.

UKOOA (2002) UKOOA Drill Cuttings Initiative Final Report, February 2002. UKOOA Drill Cuttings Initiative Executive Committee.

UKOOA (2005) UKOOA JIP 2004 Drill Cuttings Initiative Phase III. Final Report. 20132900. UKOOA.

United Nations (2025) 17 Goals of Sustainable Development. [Online] Available from: https://sdgs.un.org/goals [Accessed December 2025]

United Nations Environment Programme (UNEP) (2024). Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments. Nairobi. Available from: Emissions Gap Report 2024 | UNEP - UN Environment Programme.

United Nations Framework Convention on Climate Change (UNFCCC) (2024) Nationally determined contributions under the Paris Agreement. Synthesis report by the secretariat. https://unfccc.int/documents/641792.

United Nations Framework Convention on Climate Change (UNFCCC). (2016). The Paris Agreement. Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T. I. A. S. No 16-1104, 3156 U. N. T. S.

United Nations Framework Convention on Climate Change (UNFCCC). (2021). The Glasgow Climate Pact – Key Outcomes from COP26. [Online]. Available from: https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26 [Accessed November 2025].

United Nations Framework Convention on Climate Change (UNFCCC). (2022). Sharm el-Sheikh Climate Change Conference - November 2022. [Online]. Available from: https://unfccc.int/node/568190 [Accessed November 2025].

United Nations Framework Convention on Climate Change (UNFCCC). (2023). UN Climate Change Conference - United Arab Emirates. [Online]. Available from: https://unfccc.int/cop28 [Accessed November 2025].

United Nations Framework Convention on Climate Change (UNFCCC). (2024). UN Climate Change Conference Baku - November 2024. [Online]. Available from: https://unfccc.int/cop29 [Accessed November 2025].

Veirs, S., Veirs, V. & Wood, J.D. (2016) Ship noise extends to frequencies used for echolocation by endangered killer whales. Peer J4: e1657.

Vik, E.A., Blytt, L.D., Stang, P., Henninge, L.B. and Kjønnø,O (2014). Characterising thermal treated OBM drill cuttings. Sampling, characterisation, environmental analysis and risk assessment of offshore discharges. Prepared for the Norwegian Oil and Gas Association.

Vincent, C., Fedak, M. A., McConnell, B. J., Meynier, L., Saint-Jean, C., Ridoux, V. (2005) Status and conservation of the grey seal, Halichœrus grypus, in France. Biological Conservation, 126, pp. 62 – 73.

VisitScotland (2024) Scotland Visitor Survey 2023 – Motivations and Inspiration. Edinburgh: VisitScotland. Available at: https://www.visitscotland.org/binaries/content/assets/dot-org/pdf/research-insights/scotland-visitor-survey-2023-motivations-and-inspiration-updated.pdf [Accessed December 2025].

Webb, A., Elgie, M., Irwin, C., Pollock, C. and Barton, C. (2016) Sensitivity of offshore seabird concentrations to oil pollution around the United Kingdom: Report to Oil & Gas UK. Available from: http://jncc.defra.gov.uk/page-7373 [Accessed September 2025]

Wentworth, C.K. (1922) A scale of grade and class terms for clastic sediments. Journal of Geology, (30), pp.377-92.

Winther, N.G. and Johannessen, J.A. (2006) North Sea circulation: Atlantic inflow and its destination. Journal of Geophysical Research: Oceans, 111(C12), C12018.

WMO (World Meteorological Organization (WMO) (2025) State of the Global Climate 2024. Available from: https://library.wmo.int/records/item/69455-state-of-the-global-climate-2024 [Accessed August 2025]

Woodward, I.D., Thaxter, C., Owen, E., Aonghais, S., Cook (2019) Desk-based revision of seabird foraging ranges used for HRA screening, BTO Research Report No. 724, December 2019.

Woodward, I.D., Thaxter, C.B., Owen, E., Bolton, M., Ward, R.M. & Cook, A.S.C.P. (2024) The value of seabird foraging ranges as a tool to investigate the impact of offshore wind farms. Ocean and Coastal Management 254: doi:10.1016/j.ocecoaman.2024.107192.

World Meteorological Organization (WMO) (2019). The Global Climate in 2015–2019 / World Meteorological Organization. [Online]. Available from: https://library.wmo.int/index.php?lvl=notice_display&id=21522#.Xd7FaOhKjcs [Accessed October 2025].

World Meteorological Organization (WMO) (2023). WMO Greenhouse Gas Bulletin. [Online]. Available from: https://wmo.int/resources/publications/wmo-greenhouse-gas-bulletin-no-19 [Accessed October 2025].

World Nuclear Association (WNA). 2025. Heat Values of Various Fuels. [Online]. Available from: https://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels [Accessed December 2025]

Wright, P., Jensen, H. & Tuck, I. (2000) The influence of sediment type on the distribution of the lesser sandeel, *Ammodytes marinus*. Journal of Sea Research, [PDF].10 Jul, 44(3-4), pp.243-56. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1385110100000502 [Accessed September 2025].

Wyatt, R. (2008) Review of existing data on underwater sounds produced by the oil and gas industry. Seiche Measurements Limited. Report No. S186.

Xodus (2025) Bittern WI Pipeline Application – Vessel Traffic Study (VTS) and Collision Risk Assessment (CRA) Report. May 2025. Report No. A-303503-S25-A-REPT-001

Yapa, P.D., Zheng, L., and Chen, F.H. (2001) A model for deepwater oil/gas blowouts. Marine Pollution Bulletin 43: 234–241.

Youngblood, W.W., Blumer, M. (1975) Polycyclic aromatic hydrocarbons in the environment: homologous series in soils and recent marine sediments. Geochimica et Cosmochimica Acta. 39, 9. Pp. 1303 – 1314.

Zhang, J., Hao, Q., Li, Q., Zhao, X., Fu, X., Wang, W., He, D., Li, Y., Zhang, Z., Zhang, X. & Song, Z. (2024) Source identification of sedimentary organic carbon in coastal wetlands of the western Bohai Sea. Science of the Total Environment, 913(169282, 25-Feb-2024), Available

Zheng , L. and Yapa, P.D. (2002) Modelling gas dissolution in deepwater oil/gas spills. J. Mar. Syst. 31(4):299–309.

Zheng, L., Yapa, P.D. and Chen, F.H. (2003) A model for simulating deepwater oil and gas blowouts – Part I: Theory and model formulation. J. Hydraul. Res. 41(4):339–351.

16 Glossary

Term	Description
Annex I habitat	A habitat type listed under the EU Habitats Directive whose conservation requires the designation of Special Areas of Conservation offshore under The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended).
Annex II species	Animal or plant species of community interest whose conservation requires the designation of Special Areas of Conservation offshore under The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended).
Atmospheric Emissions	A collective term for gases and particulates released to the atmosphere.
Automatic Identification System	A marine navigation safety system that uses transponders on ships and shore-based stations to automatically transmit and receive real-time data about a vessel's identity, position, course, and speed to aid collision avoidance and vessel tracking.
Barrel of Oil Equivalent	A standardised unit of energy measurement used in the oil and gas industry. It equates different types of energy product, i.e. oil, gas, etc into a single comparable unit.
Bioaccumulation	The process where a substance, such as a pesticide or heavy metal, builds up in the tissues of an individual organism over its lifetime because the rate of intake and storage (from the environment, food, and water) is faster than the rate at which the organism can break it down and excrete it.
Blowout	A blowout occurs when gas/ oil escapes in an uncontrolled manner from a well.
Blowout Preventer (BOP)	A high-pressure safety valve or series of valves installed at the wellhead that is designed to seal the wellbore to prevent uncontrolled flow of oil, gas (blowout), or drilling fluid from the well
Bottom Hole Assembly	The section of the drill string located at the very bottom of the wellbore, immediately above the drill bit, which contains specialised tools like measurement and logging devices, motors, and stabilisers to control the direction and performance of the drilling operation.
Carbon Budget	Legally binding milestone of anthropogenic CO_2 emissions proposed every 5 years to achieve Net Zero targets.
Casing	Steel pipe cemented in place during the construction process to stabilise the wellbore.
Carbon Dioxide Equivalent	A metric used to compare the climate impact of different greenhouse gases by converting the amount of each gas into the amount of carbon dioxide that would have the equivalent global warming potential.
Conductor	The casing string that is usually put into the well first to prevent the sides of the hole from caving into the wellbore.
Cumulative Weighted Sound Exposure Level	An advanced measure of the total received acoustic energy over a specified period where the sound levels are weighted according to the hearing sensitivity of the specific marine species being studied.
Cuttings	Rock chips produced by chipping and crushing action of the drill bit.
Decibel	Denoted by dB, a logarithmic unit used to express the ratio of two values of a physical quantity used to measure the intensity of sound.
Decibels relative to one micro-Pascal	Denoted by dB re 1µPa @ 1 m, a specialized unit of measurement for underwater acoustics that defines the sound pressure level by comparing the measured acoustic pressure to a standard reference pressure of one micropascal.
Degrees Latitude	The angular distance, measured in degrees North or South of the Equator, used as the primary geographical coordinate to specify the north-south position of a point on the Earth's surface

Term	Description
Degrees Longitude	The angular distance, measured in degrees East or West of the Prime Meridian (Greenwich, UK), used as the primary geographical coordinate to specify the east-west position of a point on the Earth's surface.
Demersal	Organisms (primarily fish like cod or haddock) that live on or near the seabed (the benthic zone) and often feed on benthic invertebrates, contrasting with organisms that live entirely in the open water.
Drill Bit	The cutting tool at the very end of the drill string that rotates to grind, shear, or crush rock, creating the wellbore.
Drill String	The entire length of connected steel pipe, including the drill pipe, drill collars, and bottom hole assembly, that rotates the drill bit and provides a conduit for drilling fluid from the drilling rig to the bottom of the wellbore.
Dynamic Positioning	A computer-controlled system that automatically maintains a vessel's heading and position solely by using its own thrusters and propellers, without the need for anchors.
Easting	Easting is the distance, measured in meters or kilometres, eastward from a defined north-south line or origin point in a specific coordinate system
Effects Range Low	A sediment quality guideline concentration that represents the level below which adverse biological effects are rarely observed.
Emissions Reduction Action Plan	A company's specific strategies, targets, and scheduled activities designed to measure, manage, and significantly reduce greenhouse gas emissions and other atmospheric pollutants across its operations.
Environmental Aspect	An element of an organization’s activities, products, or services that can interact with the environment.
Environmental Baseline Survey	A systematic collection and analysis of physical, chemical, and biological data in a specific area to establish the existing environmental conditions.
Environmental Effect	Consequences of environmental impacts upon receptors.
Environmental Impact	Changes to the environment as result of environmental aspects.
Environmental Impact Assessment	A systematic process of evaluating the likely environmental consequences of a proposed project or development, aiming to ensure that environmental considerations are integrated into decision-making.
Environmental Impact Identification (ENVID)	A structured, systematic review process used to identify potential environmental hazards, impacts, and risks associated with all phases of a development project or activity.
Environmental Statement	The report on the environmental impact assessment for proposed project or development.
Epifauna	Benthic organisms that live on the surface of the seabed, either sessile or free moving.
European Protected Species	Animal and plant species listed in the Habitats Directive of the European Union, afforded strict legal protection against deliberate capture, injury, killing, or disturbance, and the damage or destruction of their breeding and resting sites
Exclusive Economic Zone	The sea zone extending up to 200 nautical miles from a country's coastline, within which the coastal state has special sovereign rights for the exploration and use of marine resources.
Far-field	The region of a propagating wave distant enough from the source that the waves behave as planar, and the intensity falls off predictably (e.g., inversely with the square of the distance from the source).
Favourable Reference Population	The ideal minimum population size for a species within a given region that is needed to ensure its long-term survival and healthy status, as defined for conservation under the EU Habitats Directive.
Field	An accumulation of hydrocarbons in the subsurface. Consists of a reservoir in a shape that will trap hydrocarbons and that is covered by an impermeable, sealing rock.

Term	Description
Finch Judgment, 2024	UK's Supreme Court ruling in 2024 that a decision to grant planning permission for an onshore oil development project at a site in Surrey was unlawful, because downstream GHG emissions from the combustion of the oil produced were not assessed in the EIA as part of the planning decision.
Flare	A controlled vent system to safely and quickly burn off unwanted or excess combustible gases to the atmosphere.
Floating Production, Storage, and Offloading (FPSO)	An FPSO is a moored floating vessel used in offshore oil and gas operations to process hydrocarbons, store oil, and offload it to tankers for transport
Global Warming Potential	An index that measures how much a specific mass of a greenhouse gas will warm the Earth over a defined time period (usually 100 years) relative to the warming caused by the same mass of carbon dioxide, which is set as the baseline with a GWP of 1.
Greenhouse Gas	Any gaseous compound in the atmosphere, such as carbon dioxide, methane, or nitrous oxide, that is capable of absorbing and re-emitting infrared radiation, thereby trapping heat and contributing to the warming of the Earth's surface known as the 'Greenhouse Effect'
Habitat Assessment	A survey and evaluation process used to determine the type, quality, condition, and distribution of habitats present in a specific area.
Harmonised Mandatory Control Scheme	A regulatory framework established by the OSPAR Commission to protect the marine environment requiring all chemicals used and discharged during offshore oil and gas operations to be tested, risk-assessed, and authorised.
High Frequency	A wave or periodic event that repeats a large number of times within a specific period.
international Council for the Exploration of the Seas (ICES) Rectangle	A standard geographical unit defined by the International Council for the Exploration of the Sea used primarily for the reporting and management of fisheries, environmental monitoring, and research within the North Atlantic and adjacent seas, with each rectangle typically measuring 1˚of longitude by 0.5˚of latitude.
Intergovernmental Panel on Climate Change (IPCC)	The United Nations body that regularly assesses the scientific basis of climate change, its impacts, future risks, and options for adaptation and mitigation, providing policymakers with comprehensive and authoritative scientific reports.
IPCC Assessment Report	A comprehensive scientific evaluation of the state of knowledge on climate change, its physical science basis, impacts, adaptation, vulnerability, and options for mitigation, published every five to seven years by the IPCC.
International Union for the Conservation of Nature	A global authority and membership union composed of both governmental and civil society organisations dedicated to addressing the world's most pressing environment and development challenges.
Joint Nature Conservation Committee	UK public body that advises the UK Government and the devolved administrations on UK-wide and international nature conservation, providing scientific evidence and data on biodiversity status and trends.
Liquified Natural Gas	Natural gas that has been cooled to minus 162°c, turning it into a liquid for easier, safer, and more economical storage and transportation.
Low Frequency	A wave or periodic event that repeats a low number of times within a specific period.
Lowest Astronomical Tide	The lowest predictable water level that can occur under any combination of astronomical conditions (Sun, Moon, and Earth alignment), excluding extreme meteorological effects like storms.
Low Toxicity Oil Based Mud	An invert emulsion mud with synthetic oil as the external phase instead of oil
Marine Conservation Zone	A type of Marine Protected Area in English waters designated under the Marine and Coastal Access Act (2009) to protect nationally important species, habitats, ecological processes and features of geological/geomorphological importance.

Term	Description
Marine Drilling Riser	The large-diameter pipe that extends from a drilling vessel to the subsea wellhead, providing a conduit for the drill string, returning drilling fluid, and maintaining pressure control.
Marine Mammal Management Units	Specific geographical areas defined by UK conservation bodies to represent distinct population segments of highly mobile marine mammals (i.e. dolphins, seals and porpoises).
Marine Protected Area	A clearly defined geographical zone in the sea that receives long-term protection of its marine life, habitats, and cultural heritage.
Measured Depth	Depth of the well as measured from the rotary table on the drilling rig, therefore includes the distance between the drilling rig and the seabed.
Mobile Offshore Drilling Unit	Any vessel or structure, such as a jack-up rig or semi-submersible, capable of engaging in drilling operations for exploring or developing offshore oil and gas reserves.
Multibeam Echosounder	An advanced sonar system that transmits multiple beams of sound waves in a fan shape perpendicular to the vessel's movement, allowing it to measure and map a wide area of the seafloor simultaneously to create high-resolution, 3D bathymetric maps.
National Transmission System	The high-pressure gas pipeline network that transmits natural gas throughout Great Britain, connecting terminals and storage facilities to the regional distribution networks.
Nationally Determined Contribution	A country's self-defined national climate action plan under the Paris Agreement, outlining its specific commitments and policies to reduce greenhouse gas emissions.
Natural Gas	A naturally occurring mixture of gaseous hydrocarbons, primarily methane, often found in underground reservoirs and used as a major source of energy
Nature Conservation Marine Protected Area	A type of Marine Protected Area in Scottish waters designated under the Marine (Scotland) Act 2010 to protect nationally important marine flora, fauna, habitats, and geological or geomorphological features.
Nautical Mile	A unit used for measuring distances at sea.
Net Zero	A state where the amount of greenhouse gases emitted is balanced by the amount removed from the atmosphere.
North Sea Transition Authority	Previously known as the Oil and Gas Authority (OGA) until March 2022, it is the UK government body responsible for regulating and enabling the effective and responsible development of oil, gas, and carbon storage within the UK Continental Shelf, while driving the transition to net zero.
Northing	Northing is the distance, measured in meters or kilometres, northward from a defined east-west line or origin point in a specific coordinate system.
Octanol-water partition coefficient	A ratio used to describe how a chemical distributes itself between two immiscible phases, providing a critical indicator of a chemical's potential to bioaccumulate in organisms.
Offshore Chemical Notification Scheme	A regulatory system in the UK that manages and controls the use and discharge of all chemicals used by the offshore oil and gas industry, ensuring that they are assessed for their environmental impact before use.
Offshore Petroleum Regulator for Environment and Decommissioning	UK Government regulator responsible for regulating the environmental and decommissioning aspects of offshore oil and gas operations and carbon capture and storage in the UK.
Oil On Cuttings	The concentration of residual oil or synthetic drilling fluid that remains adsorbed or trapped on the rock fragments (cuttings) after they are brought to the surface during drilling operations.
OSPAR Commission	An intergovernmental body formed by 15 Governments and the European Union to implement the OSPAR Convention and cooperate on measures to protect the marine environment of the North-East Atlantic Ocean

Term	Description
Paris Agreement	Adopted at COP21 in 2015 and requires all major greenhouse gas emitting countries to reduce their emissions. The aim of the Paris Agreement is to restrict global temperature change to well under 2°C above pre-industrial levels and pursue efforts to keep it below 1.5°C.
Particle Size Analysis	A laboratory technique used to determine the distribution of different sized grains within a sample of sediment, which is crucial for understanding the material's properties.
Particle Size Distribution	A fundamental characteristic of any material composed of particles, such as powders, granules, or particles dispersed. It is a statistical description that defines the relative amount of particles present according to their size.
Passive Acoustic Monitoring	The technique of using underwater hydrophones or terrestrial microphones to listen to the environment and record sounds of marine species and background marine environments.
Pelagic	The zone of the water column in a sea or ocean that is neither near the shore nor close to the seabed.
Permanent Threshold Shift	An irreversible, long-term or permanent reduction in hearing sensitivity caused by exposure to sufficiently loud noise
Piling	The process of driving piles into the seabed to provide a stable foundation for structures built in water.
Pipeline Integrity Gauge (PIG)	A tool sent through a pipeline to perform various tasks such as cleaning, inspecting, ensuring the line's structural integrity and operational efficiency.
Plankton	Any aquatic organisms, including tiny plants, animals, and bacteria, that drift in the water column and cannot swim strongly enough to counteract currents, forming the base of most marine and freshwater food webs.
Polycyclic Aromatic Hydrocarbons	A group of organic chemical compounds that are naturally present in fossil fuels, a leading indicator to monitor environmental pollutants of this nature.
Priority Marine Feature	A habitat or species of particular conservation importance, identified in Scotland, to focus marine nature conservation efforts, guide planning and licensing decisions.
Representative Concentration Pathway	A greenhouse gas concentration trajectory adopted by the IPCC for climate modelling, representing a possible future level of carbon dioxide emissions and resulting climate change.
Reservoir	The underground formation where oil and gas has accumulated. It consists of a porous rock to hold the oil or gas, and a cap rock that prevents its escape.
Root Mean Square Sound Pressure Level	The time-averaged measure of the sound pressure level over a specific duration.
Scope 1 Emissions	Greenhouse gas emissions categorised as Scope 1 emissions are those that a company makes directly.
Scope 2 Emissions	Greenhouse gas emissions categorised as Scope 2 emissions are those that a company makes indirectly such as the purchase of energy for heating buildings
Scope 3 Emissions	Greenhouse gas emissions which include all other indirect emissions that occur in the upstream and downstream activities of an organisation
Scottish Fishermen's Federation	A non-profit organization representing the interests of fishermen's associations and fishing companies across Scotland.
Shellfish	Any aquatic invertebrate with a shell or shell-like exoskeleton.
Sidescan Sonar	An acoustic device towed behind a vessel that transmits sound pulses to the seafloor on both sides, creating a photographic-like, high-resolution image of the seabed surface that highlights variations in texture and features
Similarity Profile Analysis (SIMPROF)	A statistical permutation test used in ecology to objectively determine if a set of samples, which are not grouped beforehand, contain any genuine structure or statistically distinct groups.
Soft Start	Gradual, or incremental, increase in hammer blow energy/frequency.

Term	Description
Sound Exposure Level	A cumulative measure of the total acoustic energy of a sound event over a given time period.
Sound Exposure Level, single strike (SEL_{ss})	The measurement of the total acoustic energy contained within a single, distinct impulsive sound event
Sound Pressure Level peak (SPL_{peak})	The highest absolute value of the instantaneous acoustic pressure measured during a sound event.
Special Area of Conservation	Protected areas for important marine habitats and species designated under The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended) in the UK offshore area. Special Areas of Conservation, together with Special Protected Areas, form the UK's national site network.
Special Protected Area	Protected areas for wild birds designed under The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended) in the UK offshore area. Special Protected Areas, together with Special Areas of Conservation, form the UK's national site network.
Species Distribution Model	A mathematical tool that uses species occurrence data and environmental variables (i.e. temperature and elevation) to predict the geographic area where a species is most likely to be found.
Spool	Short segment of rigid pipe with a flange or other connecting fitting at either end and is commonly used to connect flowlines and / or subsea facilities together, e.g. a subsea tree to a subsea manifold.
Statutory Nature Conservation Bodies	Public sector organizations in the UK and its devolved nations that advise the government and enforce laws concerning nature and wildlife protection.
Sub-bottom Profiler	A geophysical sonar system used to map and image the geological structure of the material below the seafloor, providing detailed cross-sectional views of the shallow layers of sediment and rock.
Tie-in	A tie-in is the process of connecting a new pipeline, facility, or equipment to an existing oil and gas system.
Tie-back	A tie-back is the connection of a new well or subsea facility to an existing production system or infrastructure.
Threshold Shift	A measurable change in an species hearing sensitivity.
Total Hydrocarbon Concentration	The sum measurement of all individual hydrocarbon compounds present in a sample.
Total Organic Carbon	The amount of carbon found in an organic compound within a sample (e.g., soil or water.
Total Organic Matter	A measurement of the organic material in a soil or sediment sample, typically derived using a loss on ignition technique.
Total Suspended Solids	A measurement of the dry weight of solid particles (i.e. sediment, organic matter) that remain suspended in a water sample.
Transboundary Impacts	Potential environmental impacts on the seabed, water column and/or atmosphere, which extend beyond the boundaries of the United Kingdom Continental Shelf.
Transboundary line	The officially established line separating the Exclusive Economic Zones or Continental Shelves of two adjacent or opposing countries in a shared sea area, such as the North Sea.
True Vertical Depth Sub Sea	The vertical distance measured from a fixed reference point down to a specific point within the wellbore.
Umbilical	Connections used between the subsea equipment and/or surface installation enabling the provision of control, power, communications and chemical services.
United Kingdom Continental Shelf	The area of the continental shelf over which the United Kingdom exercises sovereign rights for the purpose of exploring it and exploiting its natural resources, primarily oil and gas.

Term	Description
United Kingdom Continental Shelf Block	Sub-division of territorial seas for the purpose of licensing to a company or group of companies for exploration and production rights. Each block has a standard size of 10 minutes of Latitude by 12 minutes of Longitude, ~200 – 250 km^2.
Venting	The discharge of un-burnt, unwanted gases or hydrocarbons.
Volatile Organic Compounds	A large group of carbon-containing chemicals that easily become vapours or gases at room temperature that largely contribute to air pollution, smog formation, and have adverse effects on human health.
Water Based Mud	A drilling fluid that uses water as the continuous phase, mixed with various clays, polymers, and chemical additives to control well pressure, cool and lubricate the drill bit, and carry rock cuttings to the surface
Wellbore	The drilled hole that extends from the surface or seabed into the earth, used to access and produce hydrocarbons from a subsurface reservoir.
Wellhead	The unit at the surface of a well which controls pressure and connects to drilling and production equipment. The wellhead is the upper part of the well, located above the casing and under the drilling floor.
Xmas Tree	A complex arrangement of valves, spools, and fittings installed at the wellhead of an oil or gas well to control the flow of fluids from the wellbore, manage pressure, and allow access for monitoring and intervention
Zooplankton	The animal components of the plankton community, consisting mostly of tiny crustaceans, protozoans, and the eggs and larvae of larger animals, which feed on phytoplankton and are themselves prey for fish and larger animals

Appendix A: Legislation and Marine Policy

A.1 Applicable Environmental Legislation

Table A.1 provides an overview of key environmental legislation pertinent to the proposed Kyla Development.

Table A.1. Key Legislation Pertinent to the Proposed Kyla Development

Legislation	Summary of Requirements	Relevance to Kyla Development
The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 and associated guidance dated July 2021	There is a mandatory requirement for an EIA and the application for consent must be supported by an ES where the Development falls within the scope of a Schedule 1 project, namely where the extraction of oil and natural gas for commercial purposes exceeds 500 tonnes per day in the case of oil and 500,000 cubic metres per day in the case of natural gas and/or where the project involves a pipeline with a diameter of more than 800 mm and a length of more than 40 km.	The Kyla production rates exceeds the 500 tonnes per day of oil threshold therefore falls within the scope of a Schedule 1 project and triggers the requirement for an Environmental Statement.
The Offshore Chemicals Regulations 2002 (as amended)	These regulations implement OSPAR Decision 2000/2 and a number of subsidiary OSPAR Recommendations and Agreements relating to the adoption of a harmonised mandatory control system for the use and discharge of offshore chemicals. All activities that involve the use and/or discharge of chemicals during the course of offshore operations require a Chemical Permit issued under the regulations	Applications for the required Chemical Permits will be made via the DESNZ UK Energy Portal in advance of the proposed Kyla Development drilling operations, pipeline operations, well intervention (if applicable) and plug and abandonment activities commencing.
The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended)	Prohibits the discharge of oil to sea other than in accordance with the terms and conditions of a permit. Operators of offshore installations must identify all planned oil discharges to relevant waters and apply for the appropriate permits. Oil Discharge Permits will not be required for those chemicals already covered by the Offshore Chemicals Regulations (2002) as amended (i.e. base oils, lubricants etc.). The 2011 amendment redefined the term 'offshore installation' to encompass all pipelines and the term 'release' to cover all unintentional oil emissions. Intentional emissions are referred to as 'discharges'.	Produced water from the Kyla Development shall be treated by the existing Triton produced water system where it will be discharged to sea in accordance with the Triton Oil Discharge Permit.

Legislation	Summary of Requirements	Relevance to Kyla Development
The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended)	These Regulations require consent for geological surveys related to oil and gas activities. In addition, under these Regulations. It is the responsibility of the Competent Authority (OPRED) to make an appropriate assessment of the implications of any activity that might be undertaken pursuant to a UKCS licence, consent, authorisation, or approval, on a relevant site's conservation objectives, where this is likely to have a significant effect on a relevant site, alone or in combination with any other plan or project. A relevant site is any Special Area of Conservation (SAC) or Special Protection Area (SPA).	An application for a Marine Survey Consent will be made via the DESNZ UK Energy Portal in advance of future survey operations commencing.
The Conservation of Offshore Marine Habitats and Species Regulations 2017	These Regulations implement the species protection requirements of the Habitats and Birds Directives offshore (12-200 nautical miles from the coast). The Regulations also include provisions for the designation and protection of areas that host important habitats and species in the offshore marine area (i.e. SACs and SPAs). Part 5 provides powers to OPRED to issue licences for specific activities that could result in the injury or disturbance of European Protected Species (EPS injury or disturbance licences) and the potential to issue wild birds licences (providing certain licensing tests are met).	This ES has concluded that the Kyla Development activities will not injure an EPS, or deliberately disturb EPS in such a way as to be likely to impair their ability to survive, breed, or rear or nurture their young, or significantly affect the local distribution or abundance of EPS.
The Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation) Regulations 1998 (as amended)	These Regulations require that every offshore installation and oil-handling facility must have an approved oil pollution emergency plan (OPEP) in place, setting out arrangements for responding to incidents that cause or may cause a hydrocarbon pollution incident at sea. The OPEP must detail methods to prevent such pollution or reducing or minimising its effect. The 2015 Amendment Regulations implement the EU Offshore Safety Directive (2013/30/EU).	Approved OPEPs will be in place for all lifecycle phases of the Kyla Development in advance of operations commencing offshore.
Marine and Coastal Access Act 2009 (as amended) / The Marine (Scotland) Act 2010	The Marine (Scotland) Act 2010 and Marine and Coastal Access Act 2009 (known as the 'Marine Acts') established a new legislative and management framework for the marine environment, allowing the competing demands on the sea to be managed in a sustainable way across all of Scotland's seas. Marine planning matters in Scotland's inshore waters are governed by the Marine (Scotland) Act 2010, and by the Marine and Coastal Access Act 2009 for Scotland's offshore waters. The Acts also define powers to establish marine protected areas to protect natural and cultural marine features. In addition to making provisions to establish marine protected areas, they also set out how	The proposed Kyla Development, as described in this ES, has been assessed against all relevant Scottish National Marine Plan objectives and policies to confirm that the Project will not adversely impact them (refer to Section A.2 below).

Legislation	Summary of Requirements	Relevance to Kyla Development
	these are to be considered be relevant authorities at various stages, in a similar but slightly different way to HRA requirements.	
OSPAR Recommendation 2003/5 to Promote the Use and Implementation of Environmental Management Systems by the Offshore Industry	In line with the convention and reporting requirements, all operators controlling the operation of offshore installations on the UKCS should have in place an independently verified environmental management system (EMS) designed to: • Achieve the general objectives of the OSPAR Offshore Strategy; • Achieve the environmental goals of the prevention and elimination of pollution from offshore sources and of the protection and conservation of the maritime area against other adverse effects of offshore activities, and • Maintain continual improvement in environmental performance.	The Kyla field will be developed in accordance with Serica's EMS, which was successfully verified against the requirements of OSPAR 2003/5 in April 2025 by ERM CVS Limited (refer to Section 13).
OSPAR Decision 98/3 on the disposal of Disused Offshore Installations	This decision prohibits the dumping and leaving wholly or partially in place of disused offshore installations with some exceptions for large structures (derogation cases).	On cessation of production, the Kyla field will be decommissioned in accordance with the requirements of the prevailing UK and international law (refer to Section 3.6).

Legislation	Summary of Requirements	Relevance to Kyla Development
The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years. The Convention is made up of six annexes: • Annex I – sets out regulations regarding the discharge of oil into the sea and requires ships to have efficient oil separation and removal equipment onboard (transposed into UK legislation through the Merchant Shipping (Prevention of Oil Pollution) Regulations 2019 (as amended) and Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulation 2005 as amended; • Annex II – addresses the prevention of pollution by noxious liquid substances carried in bulk on ships (transposed into UK legislation through The Merchant Shipping (Dangerous or Noxious Liquid Substances in Bulk) Regulations 2018); • Annex III – addresses the prevention of pollution by harmful substances carried in packaged form (transposed into UK legislation through Merchant Shipping (Carriage of Dangerous Goods and Harmful Substances) Regulations 2024); • Annex IV – concerned with the prevention of pollution by sewage from ships (transposed into UK legislation through The Merchant Shipping (Prevention of Pollution by Sewage from Ships) Regulations 2020) (as amended); • Annex V – concerned with the prevention of pollution by garbage from ships (transposed into UK legislation through The Merchant Shipping (Prevention of Pollution by Garbage from Ships) Regulations 2020) (as amended); • Annex VI – covers prevention of air pollution from ships setting limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibiting deliberate emissions of ozone depleting substances (transposed into UK legislation by The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008 (as amended)).	The MODU and all other contracted vessels will meet MARPOL requirements throughout all stages of the Project. Further information on Serica's Waste Management strategy for the Kyla Development is provided in Section 12.

A.2 Scottish National Marine Plan

The Marine and Coastal Access Act 2009 and The Marine (Scotland) Act 2010 establish the legislative and management framework for the marine environment allowing the competing demands on the sea to be managed in a sustainable way across all of Scotland's seas. The framework includes Scotland's National Marine Plan (NMP), published in March 2015. The NMP sets out strategic policies for the sustainable Development of Scotland's marine resources out to 200 nautical miles, with the aim of trying to achieve the UK's vision of having 'clean, healthy, safe, productive and diverse seas; managed to meet the long term needs of nature and people'.

When designing, planning and assessing the potential environmental impacts from the proposed Kyla Development, Serica has paid due regard to the General Policies outlined in Chapter 4 of the NMP, the Sectoral Policies for Oil and Gas detailed in Chapter 9 of the NMP, which outline how oil and gas activities are expected to develop in the longer term and the issues to be addressed to ensure they are grown sustainably, and the Strategic Objectives outlined in Annex B of the NMP.

Tables A.2 confirms that the proposed Kyla Development will not have a significant adverse impact on the General Policies of the NMP and Table A.3 confirms that the proposed Kyla Development will not have a significant adverse impact on the Sectoral Oil and Gas Policies of the NMP.

Table A.2. General Policies Contained within Scotland's NMP that are of Relevance to the Proposed Kyla Field Development

Policy	Addressed by the Kyla Development Project
GEN 1 General planning principle: There is a presumption in favour of sustainable Development and use of the marine environment when consistent with the policies and objectives of the Plan.	Serica will ensure that the proposed Kyla Development complies with all legal requirements and does not result in a significant adverse impact on the policy goals and objectives of the NMP.
GEN 2 Economic benefit: Sustainable Development and use which provides economic benefit is encouraged when consistent with the objectives and outcomes of the Plan.	It is widely acknowledged that on the pathway to Net Zero emissions, oil and gas will continue to play an important part of the energy mix for the foreseeable future. Moreover, according to the Climate Change Committee (CCC), the UK will require 13–15 billion barrels of oil and gas equivalent in the period 2025 to 2050 but is currently only forecast to produce 4 billion (CCC, 2025; NSTA, 2025a). In a time of historically low domestic energy production with more than 40% of the UK's energy now imported, responsible development of UKCS oil and gas fields ensures that the UK meets its energy demand while retaining control over emissions. The selected Development concept for Kyla makes maximum use of existing oil and gas infrastructure and will be a contributor in the life extension of Triton FPSO. While residual operational emissions are unavoidable, the Development represents one of the lowest carbon intensity means of recovering remaining hydrocarbons in the Kyla field. Opportunities for further emissions reductions, including electrification of offshore assets and low-carbon logistics, will be assessed as part of ongoing asset stewardship and future investment planning. In addition, the Project aligns with the UK Government's strategy to maintain domestic production to preserve critical infrastructure, skills, and supply chain capacity for the energy transition.
GEN 3 Social benefit: Sustainable Development and use which provides social benefits is encouraged when consistent with the objectives of the Plan	

Policy	Addressed by the Kyla Development Project
GEN 4 Co-existence: Proposals which enable co-existence with other Development sectors and activities within the Scottish marine area are encouraged in planning and decision-making processes, when consistent with policies and objectives of the Plan.	Currently, there are no planned, consented or operational offshore wind farms or carbon capture and storage sites that would be adversely impacted by the Kyla Development. In addition, there are no commercial or capital dredging activities undertaken in the area or any sites licenced for disposal of dredged material. Shipping activity in the waters CNS is relatively low and there is ample sea room for shipping to re-route or avoid the Kyla Development location (refer to Section 4.4). Two active pipelines cross with the proposed route of the pipelines and umbilical, the CATS pipeline (PL774) operated by the Wood Group and the Langeled pipeline (PL2071) operated by GASSCO AS. Crossing designs are not yet matured, but are likely to entail concrete mattresses and rock placement, as described in Section 3.4.3. Where concrete mattresses are used as part of the crossings design, or in other open water relocations outside the 500m safety zones at Bittern and Kyla, rock cover will be provided to minimise risk of snagging with fishing gear. Serica has undertaken a scoping exercise with key stakeholders to ensure that the expectations of concerned parties have been incorporated into the Project at an early stage. The feedback received and how this has been considered by the Project is detailed in Section 1.7 of this ES. Continued liaison with other users of the area will be undertaken throughout the Project to achieve a synergistic approach to the Development of the area.
GEN 5 Climate change: Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change.	The potentially significant effects on climate from GHG emissions generated by the proposed Kyla Development are assessed in Section 9. The GHG emissions have been evaluated in the context of a global baseline scenario of GHGs, with consideration given to the impact the emissions will have on global climate change agreements, UK carbon policies and targets and associated emissions reduction pathways. The assessment has been undertaken with reference to the new DESNZ supplementary guidance for assessing the effects of downstream scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025), published following the Finch judgment, 2024.
GEN 6 Historic Environment: Development and use of the marine environment should protect and, where appropriate, enhance heritage assets in a manner proportionate to their significance.	There are no wrecks designated as historic Marine Protected Areas (hMPAs), scheduled monuments (including wrecks) or war graves within the vicinity of the proposed Kyla Development area (NMPi, 2025), nor are there any charted wrecks (UKHO, 2024). No wrecks were observed during the 2025 survey operations (refer to Section 4.4.8).

Policy	Addressed by the Kyla Development Project
GEN 9 Natural heritage: Development and use of the marine environments must: a) Comply with legal requirements for protected areas and protected species; b) Not result in significant impact on the national status of PMFs; c) Protect and, where appropriate, enhance the health of the marine area.	The environmental baseline and potential presence of protected species or habitats, including PMFs has been fully characterised in Section 4 of the ES. The ES has concluded that the Kyla Development will not result in any significant environmental effects to the marine environment provided that all identified mitigation measures are implemented (refer to assessment detailed in Sections 6 – 11).
GEN 10 Invasive non-native species: Opportunities to reduce the introduction of invasive non-native species to a minimum or proactively improve the practice of existing activity should be taken when decisions are being made.	The MODU and all other contracted vessels will comply with the IMO Ballast Water Management Convention throughout all stages of the Project.
GEN 11 Marine litter: Developers, users and those accessing the marine environment must take measures to address marine litter where appropriate. Reduction of litter must be taken into account by decision makers.	Serica and its contractors will adhere to the Waste Hierarchy Principles and will minimise the generation of waste as a priority (refer to Section 12). Vessels will have Garbage Management Plans in place in accordance with MARPOL 73/78 which will detail waste handling, storage and disposal procedures to minimise the generation of marine litter.
GEN 12 Water quality and resource: Developments and activities should not result in a deterioration of the quality of waters to which the Water Framework Directive (WFD), Marine Strategy Framework Directive or other related Directives apply.	The Marine Strategy Framework Directive aims to minimise concentrations of contaminants in biota, sediments and water. The main discharges into the marine environment from the proposed Kyla Development will occur as a result of the discharge of drill cuttings, muds, cement, completion and rig chemicals during drilling operations, chemicals during hook-up and commissioning of subsea infrastructure, including commissioning and preservation fluids and discharge of chemicals or hydrocarbons during subsea intervention activities. Once Kyla comes online, there will be an incremental increase in produced water at the Triton FPSO which will be treated by the existing Triton produced water system and discharged to sea in accordance with the Triton Oil Discharge Permit, provided the monthly average oil concentration does not exceed 30 mg/l. The effects on seabed fauna from the deposition of WBM cuttings and fine solids (from the top two well sections) are usually subtle or undetectable, although the presence of drilling material at the seabed close to the drilling location is often detectable chemically. The deeper well sections will be drilled with a LTOBM system with the LTOBM contaminated cuttings either skipped and shipped to shore for disposal or thermally treated offshore to an acceptable overboard disposal limit (<1% oil on cuttings) and discharged from the MODU. In the

Policy	Addressed by the Kyla Development Project
	event the LTOBM contaminated cuttings are discharged, significant impacts to benthic communities are not predicted as previous studies have found no evidence of significant changes to the natural benthic community or re-colonisation of the seabed when exposed to low oil on cuttings concentrations (refer to Section 7). All other discharges from the Project will be subject to rapid dilution and dispersion and are not expected to persist within the marine environment (refer to Section 10).
GEN 13 Noise: Development and use in the marine environment should avoid significant adverse effects of man-made noise and vibration, especially on species sensitive to such effects.	The potentially significant environmental impacts on sensitive marine fauna (specifically marine mammals, fish and seabirds) that may arise from underwater noise emissions generated by the Kyla Development are assessed in Section 8 of this ES. This has concluded that sensitive marine fauna may experience short term behavioural effects, but significant impacts are not predicted provided that in the event the piling operations are conducted, the Project adheres to the JNCC protocol for minimising the risk of injury to marine mammals from piling noise (JNCC, 2010b). Serica will also ensure that contractors implement the JNCC guidance for the use of Passive Acoustic Monitoring in UK waters (JNCC, 2023).
GEN 14 Air quality: Development and use of the marine environment should not result in the deterioration of air quality and should not breach any statutory air quality limits.	Impacts to air quality arising from the atmospheric emissions generated during the proposed Kyla Development operations are predicted to be negligible. Emissions will disperse rapidly from source given the open and dynamic metocean environment in the CNS region.
GEN 17 Fairness: All marine interests will be treated with fairness and in a transparent manner when decisions are being made in the marine environment.	These policies have been addressed in the EIA process through the scoping exercise, as reported in Section 1.7 of this ES. In addition, Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 also allows for public participation following the submission of the ES.
GEN 18 Engagement: Early and effective engagement should be undertaken with the general public and all interested stakeholders to facilitate planning and consenting processes.	
GEN 19 Sound evidence: Decision making in the marine environment will be based on sound scientific and socio-economic evidence.	This ES has been based on robust data sources to inform the EIA process, including the environmental baseline survey and habitat assessment undertaken at the Kyla Development location in 2025 (refer to Section 4.1).
GEN 20 Adaptive management: Adaptive management practices should take account of new data and information in decision making, informing future decisions and future iterations of policy.	As noted above, this ES has been based on robust data sources to inform the EIA process. Serica will ensure the continued use of the most up-to-date data and research when assessing the impact of the proposed Kyla Development.

Policy	Addressed by the Kyla Development Project
GEN 21 Cumulative impacts: Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision-making and plan implementation.	Cumulative impacts have been considered during the EIA process and are assessed in the Sections 6 to 11 of this ES. No significant cumulative impacts are predicted provided that all identified mitigation measures are implemented.

Table A.3. Sector Policies Related to Oil and Gas Developments According to Scotland's National Marine Plan

Policy	Supported Strategic Objectives	Addressed by the Kyla Development Project
OIL & GAS 1: The Scottish Government will work with OPRED, the NSTA and the industry to maximise and prolong oil and gas exploration and production whilst ensuring that the level of environmental risks associated with these activities are regulated. Activity should be carried out using the principles of BAT and BEP. Consideration will be given to key environmental risks including the impacts of noise, oil and chemical contamination and habitat change.	Economic Social Climate Change – Adaptation Marine Ecosystem	The proposed Kyla Development concept has been selected and defined with consideration to the central obligation of the NSTA Strategy (refer to Section 2). The selected concept reflects the optimal Development plan for Kyla, maximising hydrocarbon recovery whilst minimising capital risk and costs, maximising use of existing North Sea oil and gas infrastructure, and significantly reduces the carbon footprint of production when compared with standalone or long-distance tie-back alternatives. Key environmental risks have been identified in the assessment sections of this ES (refer to Sections 6 – 11).
OIL & GAS 2: Where re-use of oil and gas infrastructure is not practicable, either as part of oil and gas activity or by other sectors such as carbon capture and storage, decommissioning must take place in line with standard practice, and as allowed by international obligations. Re-use or removal of decommissioned assets from the seabed will be fully supported where practicable and adhering to relevant regulatory processes.	Economic Social	On cessation of production, the Kyla field will be decommissioned in accordance with the requirements of the prevailing UK and international law (refer to Section 3.6).
OIL & GAS 3: Supporting marine and coastal infrastructure for oil and gas Developments, including for storage, should utilise the minimum space needed for activity and should take into account environmental and socio-economic constraints.	Economic Marine Ecosystem	The selected Development concept for Kyla makes maximum use of existing oil and gas infrastructure, thereby minimising the impact on the environment and other users of the sea (refer to Section 2).
OIL & GAS 5: Consenting and licensing authorities should have regard to the potential risks, both now and under future climates, to oil and gas operations in Scottish waters, and be satisfied that installations are appropriately sited and designed to take account of current and future conditions.	Social Marine Ecosystem	The Kyla field will be developed in a way that will not result in significant effects to the marine environment. With respect to future climate conditions, the Kyla field is expected to produce hydrocarbons for ca. eight years, whilst design considerations have accounted for 100-year extreme weather events. In this context, the Kyla Development is appropriately designed for the location for which it is proposed.

Policy	Supported Strategic Objectives	Addressed by the Kyla Development Project
OIL & GAS 6: Consenting and licensing authorities should be satisfied that adequate risk reduction measures are in place, and that operators should have sufficient emergency response and contingency strategies in place that are compatible with the National Contingency Plan and the Offshore Safety Directive.	Social Marine Ecosystem	Accidental events that may arise during the Kyla field Development have been assessed in Section 11 this ES, along with measures in order prevent their occurrence or to minimise any potentially significant adverse effects.

Appendix B: ENVID Registers

To inform the Kyla Development EIA, an ENVironmental and socio-economic impact IDentification (ENVID) workshop was undertaken to identify those Project activities (or aspects) which should be subject to detailed assessment in the ES.

The ENVID used the Evaluation of Significance Criteria (as documented in Section 5 of the ES) to determine the likely significance of effects on the environment.

For planned activities, the significance of environmental effects has been evaluated by considering the sensitivity of the receptor affected in combination with the magnitude of impact. For the purposes of this assessment, aspects with a significance score of Minor / Moderate, Moderate, Moderate / Major or Major have been taken forward for detailed assessment in the ES.

For unplanned events, significance has been determined using a risk assessment approach, where the likelihood (probability) of the unplanned event occurring is considered against the consequence (significance of effect) if the event was to occur. For the purposes of this assessment, unplanned events with a significance score of Medium or High have been taken forward for detailed assessment in the ES.

The results of the ENVID workshop (which took place on the 22nd September 2025) are documented in the ENVID Registers provided in this Appendix, refer to Tables B.1 to B.4.

Table B.1: Drilling ENVID Matrix

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
1.1	Physical Presence	Presence of AHVs during pre-lay, hookup and removal of MODU anchors and ground chains	Shipping	High	Medium	**Medium**	Minor	**Minor**	Vessels will present a navigational hazard and cause displacement of commercial fisheries.	Main operators of vessels passing in proximity to Kyla will be provided with advanced notice of the proposed operations; Notification to Kingfisher Bulletin.	**No**
			Commercial Fishing	High	Medium	**Medium**	Minor	**Minor**			
1.2		Presence of pre-laid MODU anchors and ground chains	Commercial Fishing	High	Medium	**Medium**	Moderate	**Minor / Moderate**	Potential snagging hazard to fishing gears towed along the seabed.	Consent to Locate will be in place; Notification to Kingfisher Bulletin. Guard vessel will be in place as required by the CtL	**Yes**
1.3		Presence of MODU (including anchors and ground chains) and supply / support vessels during drilling operations	Shipping	High	Medium	**Medium**	Moderate	**Minor / Moderate**	Vessels will present a navigational hazard and cause displacement of commercial fisheries.	A 500 m safety zone will be in place, which will be patrolled by a dedicated ERRV; Reporting of the rig move will take place in line with the requirements of Part 4a of the Energy Act and HSE Operations Notice 6 guidance; Site-specific collision risk management plan to be developed; Consent to Locate will be in place.	**Yes**
			Commercial Fishing	High	Medium	**Medium**	Moderate	**Minor / Moderate**			
			Marine Mammals	High	Very High	**High**	Negligible	**Negligible**	Potential for collision between moving vessels and marine mammals.		**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
			Seabirds	High	Very High	**High**	Negligible	**Negligible**	Potential for disturbance / displacement from foraging areas.		
1.4	Physical Presence	Artificial light emitted from the MODU and support vessels	Seabirds	High	Very High	**High**	Negligible	**Negligible**	Seabirds are easily disorientated by intense sources of artificial light.		**No**
1.5		Physical presence of wellhead and xmas tree	Commercial Fishing	High	Medium	**Medium**	Major	**Moderate**	Potential snagging hazard to fishing gears towed along the seabed.	Wellhead will be located within 500 m safety zone and will be marked as a hazard on admiralty charts and entered into the FishSafe system; Consent to Locate will be in place.	**Yes**
1.6	Seabed Disturbance	Mooring of semi-submersible MODU (anchors and ground chains)	Seabed Sediments	High	Low	**Low**	Major	**Minor**	Localised abrasion to the seabed and potential for anchor scars and mounds upon removal. Localised abrasion from lateral movement of anchor chains. Potential to disturb contaminated sediments at Kyla from prior drilling operations. Physical disturbance and smothering of benthic communities. Impacts	Anchors will be set at the optimum angle for the local seabed sediments, reducing the potential drag across the seabed and helping them to become suitably embedded; The length of ground chains used for mooring the MODU will be optimised to maintain MODU stability and integrity; Anchors and chains will be placed in accordance with site survey results so as to use best	**Yes**
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**	to foraging behaviour of fish and displacement from spawning and nursery areas.	endeavours to avoid damage to sensitive seabed habitats.	**No**
1.7		Deposit of drill cuttings and cement on the seabed.	Seabed Sediments	High	Low	**Low**	Major	**Minor**	Cuttings pile will alter the seabed topography and sediment structure. Physical disturbance and smothering of benthic communities. Impacts to foraging behaviour of fish and displacement from spawning and nursery areas.	Minimise chemical use, use less hazardous chemicals; Thermal cuttings treatment is being evaluated to treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% oil on cuttings).	**Yes**
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			
1.8	Underwater Noise Emissions	Use of propellers / DP thrusters on vessels	Marine Mammals	High	Very High	**High**	Negligible	**Negligible**	Potential behavioural disturbance or physiological impacts to sensitive marine fauna species.	Optimise vessel movements by careful planning	**No**
			Fish & Shellfish	High	Very High	**High**	Negligible	**Negligible**			
			Seabirds	High	Very High	**High**	Negligible	**Negligible**			
1.9		Operation of equipment on MODU (e.g. rotating machinery)	Marine Mammals	High	Very High	**High**	Negligible	**Negligible**	Potential behavioural disturbance or physiological impacts to sensitive marine fauna species.	Operational and maintenance procedures will aim to optimise the efficiency of equipment.	**No**
			Fish & Shellfish	High	Very High	**High**	Negligible	**Negligible**			
			Seabirds	High	Very High	**High**	Negligible	**Negligible**			

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
1.10	Airborne noise emissions	Use of helicopters	Seabirds	High	Very High	**High**	Negligible	**Negligible**	Potential for disturbance / displacement from foraging areas.	Optimise helicopter movements by careful planning	**No**
1.11	Atmospheric Emissions	Fuel burnt for power generation on the MODU, vessels and helicopters	Air Quality	Very High	Low	**Low**	Negligible	**Negligible**	Emissions of combustion products (particularly CO_2, CH_4, N_2O) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, SO_2, VOCs) can contribute to the formation of local tropospheric ozone and	Supplier's environmental footprints will be factored into the tender evaluation process; Maintenance regime will ensure all equipment will operate at optimum efficiency, minimising the overall fuel consumption; The combustion plants onboard the MODU will be built to be fuel efficient and to meet all current emission standards; Use of low sulphur fuels according to IMO requirements; Optimise drilling programme including vessel movements by	**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
1.12			Climate	Medium	Very High	**Very High**	Substantial	**Major**	photochemical smog, resulting in a reduction in local air quality.	careful planning to minimise fuel use; Look to have ISO50001 in place for MODU and vessels. Consider the use of Hydrotreated Vegetable Oil (HVO) fuel in place of Marine Gas Oil (MGO). Emissions forecasting and use of 'live' emissions tracking to optimise MODU engine use etc by using Stepwise or a similar provider.	**Yes**
1.13	Marine Discharges	Discharge of cuttings at the sea surface	Water Quality	Very High	Low	**Low**	Moderate	**Minor**	Decline in water quality, including temporary increase in suspended sediment levels and turbidity in the water column, which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish.	Thermal cuttings treatment is being evaluated to treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% oil on cuttings); Screening Direction and Chemical Permit will be in place.	**Yes**
			Plankton	High	Medium	**Medium**	Moderate	**Minor / Moderate**			
			Fish & Shellfish	High	Very High	**Medium**	Moderate	**Minor / Moderate**			
1.14		Discharge of drilling, cementing,	Water Quality	Very High	Low	**Low**	Moderate	**Minor**	Decline in water quality which could have toxic effects on marine biota particularly	Chemical use and discharge will be minimised to as low as practically possible;	**Yes**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
		completion and rig chemicals	Plankton	High	Medium	**Medium**	Moderate	**Minor / Moderate**	phytoplankton, zooplankton and fish.	Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile. A Chemical Risk Assessment will be undertaken in advance of drilling ops to support the Chemical Permit as per the requirements of the Offshore Chemicals Regulations 2002 (as amended).	
			Fish & Shellfish	High	Very High	**Medium**	Moderate	**Minor / Moderate**			
1.15		MODU and support vessels - discharge of grey/blackwater	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Increased BOD (from organic and other nutrient matter in detergents and human waste) may ultimately lead to an increase in opportunistic species.	Waste water will be disposed of in accordance with the requirements of the MARPOL convention and UK regulations	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			
			Fish & Shellfish	Very High	Very High	**Medium**	Negligible	**Negligible**			
1.16		MODU and support vessels - release of food waste	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Increased BOD (from organic and other nutrient matter) may ultimately lead to an increase in opportunistic species.	Food waste will be disposed of to meet the requirements of MARPOL convention and UK regulations.	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			
			Fish & Shellfish	Very High	Very High	**Medium**	Negligible	**Negligible**			
			Seabirds	Very High	Very High	**Medium**	Negligible	**Negligible**			
1.17		Oily water discharges from	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Decline in water quality which could have toxic effects on marine biota	Deck drainage water will be sampled prior to discharge to	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
		deck drains on MODU	Fish & Shellfish	Very High	Very High	**Medium**	Negligible	**Negligible**	particularly phytoplankton, zooplankton and fish.	ensure the oil in water concentration is <40 mg/l; An Oil Discharge Permit will be in place.	
			Seabirds	Very High	Very High	**Medium**	Negligible	**Negligible**			
			Marine Mammals	Very High	Very High	**Medium**	Negligible	**Negligible**			
1.18		MODU and support vessels - discharge of ballast water	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Potential to introduce alien species, which could alter the local and possibly the wider ecosystem.	Compliance with the IMO Ballast Water Management Convention	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			
			Fish & Shellfish	Medium	Very High	**Very High**	Negligible	**Negligible**			
			Seabirds	High	Very High	**High**	Negligible	**Negligible**			
			Marine Mammals	High	Very High	**High**	Negligible	**Negligible**			
1.19	Solid Waste	General operational waste - non-hazardous & hazardous	Population & Human Health	Very High	Very High	**Medium**	Negligible	**Negligible**	Effects of onshore disposal of waste depends on the nature of waste and disposal site. Potential effects on future land use options for waste disposal sites. Potential for localised land and air contamination.	Waste will be dealt with in accordance with regulatory requirements. The principles of the Waste Management Hierarchy will be followed, licensed waste contractors will be used and Waste Management Duty of Care audits will be carried out. Vessels will conform to their own Waste Management Plans. A project Waste Management	**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
										Plan will be put in place and followed.	
1.20	Use of Resources	Resource use during drilling operations	Population & Human Health	Medium	Very High	**Very High**	Negligible	**Negligible**	Depletion of natural resources leading to climate change, biodiversity loss and pollution, as well as socio-economic consequences for the world wide population	Minimise the use of natural resources, as far as practicable	**No**

Table B.2: Subsea Installations and Commissioning ENVID Matrix

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.1	Physical Presence	Physical presence of DP installation and commissioning vessels	Shipping	High	Medium	**Medium**	Moderate	**Minor / Moderate**	Potential for the vessels to be a navigational hazard as during installation activities, vessel manoeuvrability will be restricted	Adherence to Marine law, vessel radar and AIS, Notices to Mariners, Kingfisher Bulletin.	**Yes**
			Commercial Fishing	High	Medium	**Medium**	Moderate	**Minor / Moderate**			
2.2			Marine Mammals	High	Very High	**High**	Negligible	**Negligible**	Potential for collision between moving vessels and marine mammals.		**No**
			Seabirds	High	Very High	**High**	Negligible	**Negligible**	Potential for disturbance / displacement from foraging areas.		
2.3		Presence of subsea infrastructure and associated protection material (rock, mattresses)	Commercial Fishing	High	Medium	**Medium**	Major	**Moderate**	Loss of sea area for other users (i.e. loss of access to fishing grounds) and potential snagging hazard.	Kyla safety zone and seabed infrastructure will be clearly marked on navigation charts; Subsea facilities at Kyla will be designed for fishing interaction.	**Yes**
2.4		Artificial light emitted from DP installation and commissioning vessels	Seabirds	High	Very High	**High**	Negligible	**Negligible**	Seabirds are easily disorientated by intense sources of artificial light.	Temporary disturbance, metocean conditions drive operations to target summer weather (when hours of darkness are shorter).	**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.5	Seabed Disturbance	Laying of production pipelines and umbilical on the seabed	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Potential to disturb seabed sediments, including contaminated sediments at Kyla from prior drilling operations and affect benthic communities	Route selection and optimisation based on acquired Environmental, Geophysical, and Geotechnical survey data; Minimise working corridors, as far as possible.	**Yes**
			Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**			
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			**No**
2.6		Trenching and burial of pipelines and umbilical	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Potential to disturb seabed sediments, including contaminated sediments at Kyla from prior drilling operations and affect benthic communities	Route selection and optimisation based on acquired Environmental, Geophysical, and Geotechnical survey data; Minimise working corridors, as far as possible.	**Yes**
			Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**			
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.7	Seabed Disturbance	Installation of tie-in spools & jumpers at Kyla and Bittern	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Potential to disturb seabed sediments, including contaminated sediments at Kyla from prior drilling operations and affect benthic communities	Subsea infrastructure layout optimised to minimise footprint/seabed disturbance.	**Yes**
			Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**			
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			**No**
2.8		Installation of 'fishing friendly' valve skid at Kyla (either a piled or gravity based structure) and tie-in structure (either a piled or gravity based structure) at Bittern	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Potential to disturb seabed sediments, including contaminated sediments at Kyla from prior drilling operations and affect benthic communities	Subsea infrastructure layout optimised to minimise footprint/seabed disturbance.	**Yes**
			Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**			
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.9	Seabed Disturbance	Laying of rock, concrete mattresses for protection / stability / trench transitions	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Potential to disturb seabed sediments, affect benthic communities with rock / mattresses / grout bags introducing a novel hard substrata.	Minimise amount of deposited material whilst still achieving the required level of stabilisation / protection.	**Yes**
			Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**			
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			**No**
2.10		Construction of pipeline crossings (Langeled and CATS pipelines)	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Potential to disturb seabed sediments, affect benthic communities with rock, plinths and mattresses introducing a novel hard substrata.	Crossing designs optimised to minimise material deposited.	**Yes**
			Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**			
			Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**			
			Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			**No**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.11	Underwater Noise Emissions	Use of propellers / DP thrusters on installation and commissioning vessels, including general noise and vibration of equipment whilst operating	Fish & Shellfish	High	Very High	**High**	Negligible	**Negligible**	Potential behavioural disturbance or physiological impacts to sensitive marine fauna species.	Optimise vessel movements by careful planning	**No**
			Marine Mammals	High	Very High	**High**	Negligible	**Negligible**			
			Seabirds	High	Very High	**High**	Negligible	**Negligible**			
2.12		Piling operations to install the valve skid and tie-in structure	Fish & Shellfish	Medium	Very High	**Very High**	Minor	**Minor / Moderate**	Potential behavioural disturbance or physiological impacts to sensitive marine fauna.	Implement statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise	**Yes**
			Marine Mammals	Medium	Very High	**Very High**	Minor	**Minor / Moderate**			
			Seabirds	Medium	Very High	**Very High**	Minor	**Minor / Moderate**			
2.13	Atmospheric Emissions	Fuel burnt for power generation on installation and commissioning vessels	Air Quality	Very High	Low	**Low**	Negligible	**Negligible**	Emissions of combustion products (particularly CO_2, CH_4, N_2O) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, SO_2, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality.	Supplier's environmental footprints will be factored into the tender evaluation process; Maintenance regime will ensure all equipment will operate at optimum efficiency, minimising the overall fuel consumption; Use of low sulphur fuels according to IMO requirements; Optimise subsea installation and commissioning programme including vessel movements by careful planning to minimise fuel use.	**No**
2.14			Climate	Medium	Very High	**Very High**	Substantial	**Major**			**Yes**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.15	Marine Discharges	Use and discharge of chemicals during hook-up and commissioning of subsea infrastructure, including commissioning and preservation fluids	Water Quality	Very High	Low	**Low**	Moderate	**Minor**	Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish.	Chemical use and discharge will be minimised to as low as practically possible; Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile. A Chemical Risk Assessment will be undertaken in advance of pipeline installation ops to support the Chemical Permit as per the requirements of the Offshore Chemicals Regulations 2002 (as amended).	**Yes**
			Plankton	High	Medium	**Medium**	Moderate	**Minor / Moderate**			
			Fish & Shellfish	High	Very High	**Medium**	Moderate	**Minor / Moderate**			
2.16		Installation and commissioning vessels - discharge of grey/blackwater	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Increased BOD (from organic and other nutrient matter in detergents and human waste) may ultimately lead to an increase in opportunistic species.	Waste water will be disposed of in accordance with the requirements of the MARPOL convention and UK regulations	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			
			Fish & Shellfish	Very High	Very High	**Medium**	Negligible	**Negligible**			
2.17		Installation and support vessels - release of food waste	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Increased BOD (from organic and other nutrient matter) may ultimately lead to an increase in opportunistic species.	Food waste will be disposed of to meet the requirements of MARPOL convention and UK regulations.	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			
			Fish & Shellfish	Very High	Very High	**Medium**	Negligible	**Negligible**			
			Seabirds	Very High	Very High	**Medium**	Negligible	**Negligible**			

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
2.18	Marine Discharges	Installation and commissioning vessels - discharge of ballast water	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Potential to introduce alien species, which could alter the local and possibly the wider ecosystem.	Compliance with the IMO Ballast Water Management Convention	**No**
			Plankton	Very High	Medium	**Low**	Negligible	**Negligible**			
			Fish & Shellfish	Medium	Very High	**Very High**	Negligible	**Negligible**			
			Seabirds	High	Very High	**High**	Negligible	**Negligible**			
			Marine Mammals	High	Very High	**High**	Negligible	**Negligible**			
2.19	Solid Waste	General operational waste - non-hazardous & hazardous	Population & Human Health	Very High	Very High	**Medium**	Negligible	**Negligible**	Effects of onshore disposal of waste depends on the nature of waste and disposal site. Potential effects on future land use options for waste disposal sites. Potential for localised land and air contamination.	Waste will be dealt with in accordance with regulatory requirements. The principles of the Waste Management Hierarchy will be followed, licensed waste contractors will be used and Waste Management Duty of Care audits will be carried out. Vessels will conform to their own Waste Management Plans. A project Waste Management Plan will be put in place and followed.	**No**
2.20	Use of Resources	Resource use during installation and commissioning operations	Population & Human Health	Medium	Very High	**Very High**	Negligible	**Negligible**	Depletion of natural resources leading to climate change, biodiversity loss and pollution, as well as socio-economic consequences for the world wide population	Minimise the use of natural resources, as far as practicable	**No**

Table B.3: Production, Inspection and Maintenance ENVID Matrix

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
3.1	Physical Presence	Ongoing presence of subsea infrastructure and protection material (rocks and mattresses)	Commercial Fishing	High	Medium	**Medium**	Major	**Moderate**	Loss of sea area for other users (i.e. loss of access to fishing grounds) and potential snagging hazard.	Kyla safety zone and seabed infrastructure will be clearly marked on navigation charts; Subsea facilities at Kyla will be designed for minimising fishing gear interaction.	**Yes**
3.2	Seabed Disturbance	Inspection, maintenance and repair of subsea infrastructure	Water Quality	Very High	Low	**Low**	Negligible	**Negligible**	Potential to disturb seabed sediments and affect benthic communities		**No**
			Seabed Sediments	High	Very High	**High**	Negligible	**Negligible**			
			Benthic Communities	High	Very High	**High**	Negligible	**Negligible**			
			Fish & Shellfish	High	Very High	**High**	Negligible	**Negligible**			
			Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**			

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
3.3	Atmospheric Emissions	Incremental atmospheric emissions at the Triton FPSO (host facility) as a result of Kyla coming online	Air Quality	Very High	Low	**Low**	Negligible	**Negligible**	Emissions of combustion products (particularly CO_2, CH_4, N_2O) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, SO_2, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality.	Triton FPSO subject to UK ETS Permit; Implementation of Triton ERAP.	**No**
3.4			Climate	Medium	Very High	**Very High**	Substantial	**Major**			**Yes**
3.5		Incremental atmospheric emissions at Triton FPSO due to additional gas cold vented from oil storage tanks as a result of Kyla production	Air Quality	Very High	Low	**Low**	Negligible	**Negligible**	Emissions of combustion products (particularly CO_2, CH_4, N_2O) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, SO_2, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality.		**No**
3.6			Climate	Medium	Very High	**Very High**	Substantial	**Major**			**Yes**

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
3.7		End use emissions from burning the extracted hydrocarbons	Air Quality	Very High	Low	**Low**	Negligible	**Negligible**	Emissions of combustion products (particularly CO_2, CH_4, N_2O) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, SO_2, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality.		**No**
3.8			Climate	Medium	Very High	**Very High**	Substantial	**Major**			
3.9	Marine Discharges	Incremental increase in produced water discharges at the Triton FPSO (host facility) as a result of Kyla coming online	Water Quality	Very High	Low	**Low**	Major	**Minor**	Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish.	Produced water will be separated using existing facilities on the Triton FPSO and discharged at hydrocarbon concentrations of <30 mg/l in accordance with the annual Oil Discharge Permit.	**Yes**
			Plankton	High	Medium	**Medium**	Major	**Moderate**			
			Fish & Shellfish	High	Very High	**Medium**	Major	**Moderate**			

Ref No.	Environmental Issue	Project Activity	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Significance	Potential Impacts	Mitigation Measures	Scoped into EIA
3.10		Discharge of chemicals or hydrocarbons during subsea intervention activities (IRM)	Water Quality	Very High	Low	**Low**	Moderate	**Minor**	Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish.	Chemical use and discharge will be minimised to as low as practically possible; Chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile, where possible; A Chemical Risk Assessment will be undertaken in advance of IRM ops to support the Chemical Permit; A term Oil Discharge Permit will be in place for the discharge of hydrocarbons as per the requirements of Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended).	**Yes**
			Plankton	High	Medium	**Medium**	Moderate	**Minor / Moderate**			
			Fish & Shellfish	High	Very High	**Medium**	Moderate	**Minor / Moderate**			

Table B.4: Unplanned Events ENVID Matrix

Ref No.	Unplanned Event	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Consequence	Likelihood	Risk	Potential Impacts	Mitigation Measures	Scoped into EIA
4.1	Dropped Objects	Oil & Gas	Very High	Medium	**Low**	Negligible	**Negligible**	Possible	Low	Dropped objects may pose a risk to subsea infrastructure or present a snagging risk to trawlers.	Any dropped objects to be immediately reported to the regulator (via a PON2) and procedures will be in place to recover objects, where possible; Debris will be identified during post work surveys and anything that cannot be recovered will be reported to the relevant authorities to be included on navigation charts; Subsea infrastructure to be designed for dropped objects as applicable. Installation and SIMOPS study to be carried out. Dropped objects study to be carried out before MODU arrival. Safe handling and lifting procedures to be followed.	**No**
		Commercial Fishing	High	Medium	**Medium**	Negligible	**Negligible**	Possible	Low			

Ref No.	Unplanned Event	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Consequence	Likelihood	Risk	Potential Impacts	Mitigation Measures	Scoped into EIA
4.2	Small release of hydrocarbons / chemicals to sea (e.g. from drains, bunkering operations etc.) during drilling, installation and commissioning or maintenance and well intervention activities	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Possible	Low	May temporarily affect water quality and impact species within the water column.	MODU / vessels will be designed, managed and maintained to prevent spills; Crews will be adequately trained and regular exercises held; Bunkering procedures will be put in place.	**No**
		Seabed Sediments	Very High	Low	**Low**	Minor	**Minor**	Possible	Low			
		Benthic Communities	High	Very High	**High**	Minor	**Minor**	Possible	Low			
		Fish & Shellfish	High	Very High	**High**	Minor	**Minor**	Possible	Low			
		Marine Mammals	High	Very High	**High**	Minor	**Minor**	Possible	Low			
4.3	Small release of hydraulic fluid, e.g. from ROV operations / hydraulic equipment / subsea control system failure	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Possible	Low	May temporarily affect water quality and impact species within the water column.	Appropriate maintenance, and pre-use checks on hydraulic equipment and ROVs PON1 reporting systems in place in the case of a release. Cefas registered hydraulic chemicals in use. Closed loop control system in place for subsea facilities.	**No**
		Plankton	Very High	Low	**Low**	Minor	**Minor**	Possible	Low			
		Fish & Shellfish	High	Very High	**High**	Minor	**Minor**	Possible	Low			
		Seabirds	High	Very High	**High**	Minor	**Minor**	Possible	Low			
		Marine Mammals	High	Very High	**High**	Minor	**Minor**	Possible	Low			

Ref No.	Unplanned Event	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Consequence	Likelihood	Risk	Potential Impacts	Mitigation Measures	Scoped into EIA
4.4	MODU or vessel collision (loss of diesel inventory) (MAH)	Water Quality	Very High	Low	**Low**	Moderate	**Minor**	Unlikely	Low	Release of fuel oil to sea may impact species within the water column, on the sea surface and in coastal habitats.	Consent to Locate will be in place for the MODU; 500m safety zone will be designated around the MODU and dedicated ERRV present; Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices; Adherence to Marine law; Vessel radar and AIS; Approved OPEP and CIP in place.	**Yes**
		Seabed Sediments	High	Very High	**High**	Moderate	**Moderate**	Unlikely	Medium			
		Plankton	Very High	Low	**Low**	Moderate	**Minor**	Unlikely	Low			
		Benthic Communities	High	Very High	**High**	Moderate	**Moderate**	Unlikely	Medium			
		Fish & Shellfish	Medium	Very High	**Very High**	Moderate	**Moderate / Major**	Unlikely	Medium			
		Seabirds	Medium	Very High	**Very High**	Moderate	**Moderate / Major**	Unlikely	Medium			
		Marine Mammals	Medium	Very High	**Very High**	Moderate	**Moderate / Major**	Unlikely	Medium			
		Marine Protected Areas	Medium	Very High	**Very High**	Moderate	**Moderate / Major**	Unlikely	Medium			
		Shipping	High	Very High	**High**	Moderate	**Moderate**	Unlikely	Medium			
		Commercial Fishing	High	Very High	**High**	Moderate	**Moderate**	Unlikely	Medium			
		Tourism & Leisure	High	Medium	**Medium**	Moderate	**Minor / Moderate**	Unlikely	Medium			
		Population & Human Health	Medium	Very High	**Very High**	Moderate	**Moderate / Major**	Unlikely	Medium			

Ref No.	Unplanned Event	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Consequence	Likelihood	Risk	Potential Impacts	Mitigation Measures	Scoped into EIA
4.5	Well blowout (releasing large quantities of hydrocarbons) in the event of a loss of well control (MAH)	Water Quality	Very High	Low	**Low**	Substantial	**Minor / Moderate**	Rare	Low	Release of hydrocarbons to sea may impact species within the water column, on the sea surface and in coastal habitats.	Well design and construction reviewed by an independent well examiner; Safety and Environmental Critical Elements will be identified, and a suitable maintenance and testing schedule applied to each; Crews will be adequately experienced, trained in well control techniques and supervised; During drilling ops, weighted drilling fluids will provide the primary barrier and the downhole pressures will be carefully controlled and monitored, with the secondary barrier, the BOP, regularly maintained and tested; Emergency drills will be held regularly; An approved OPEP, emergency response plans and equipment will be in place; OSRL Tier 2/3 support and capping device available.	**Yes**
		Seabed Sediments	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Plankton	Very High	Low	**Low**	Substantial	**Minor / Moderate**	Rare	Low			
		Benthic Communities	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Fish & Shellfish	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Seabirds	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Marine Mammals	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Marine Protected Areas	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Shipping	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Commercial Fishing	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Tourism & Leisure	High	Medium	**Medium**	Substantial	**Moderate / Major**	Rare	Medium			
		Population & Human Health	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			

Ref No.	Unplanned Event	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Consequence	Likelihood	Risk	Potential Impacts	Mitigation Measures	Scoped into EIA
4.6	Production pipeline rupture, releasing large quantities of hydrocarbons to sea	Water Quality	Very High	Low	**Low**	Substantial	**Minor / Moderate**	Rare	Medium	Release of hydrocarbons to sea may impact species within the water column, on the sea surface and in coastal habitats.	Facilities will be subject to stringent design specifications; Routine monitoring of pipeline pressure and temperature will be undertaken; Automatic and manual shutdown systems in place; Periodic ROV inspection of the pipeline will be undertaken; Maintaining pipeline integrity KPIs.	**Yes**
		Seabed Sediments	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Plankton	Very High	Low	**Low**	Substantial	**Minor / Moderate**	Rare	Medium			
		Benthic Communities	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Fish & Shellfish	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Seabirds	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Marine Mammals	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Marine Protected Areas	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
		Shipping	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Commercial Fishing	High	Very High	**High**	Substantial	**Major**	Rare	Medium			
		Tourism & Leisure	High	Medium	**Medium**	Substantial	**Moderate / Major**	Rare	Medium			
		Population & Human Health	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			

Ref No.	Unplanned Event	Receptor	Resistance & Resilience	Value	Receptor Sensitivity	Magnitude of Impact	Consequence	Likelihood	Risk	Potential Impacts	Mitigation Measures	Scoped into EIA
4.7	Gas lift pipeline rupture, releasing large quantities of gas	Air Quality	Very High	Low	**Low**	Minor	**Minor**	Rare	Low	Atmospheric emissions due to gas release	Facilities will be subject to stringent design specifications; Routine monitoring of pipeline pressure and temperature will be undertaken; Automatic and manual shutdown systems in place; Periodic ROV inspection of the pipeline will be undertaken; Maintaining pipeline integrity KPIs.	**Yes**
		Climate	Medium	Very High	**Very High**	Substantial	**Major**	Rare	Medium			
4.8	Deposit of additional rock to rectify upheaval buckling and interaction with fishing gear	Water Quality	Very High	Low	**Low**	Minor	**Minor**	Possible	Medium	Potential to disturb seabed sediments and affect benthic communities	Minimise amount of rock deposited, as far as practicable; Periodic ROV inspection of the pipeline will be undertaken; Maintaining pipeline integrity KPIs.	**Yes**
		Seabed Sediments	High	Very High	**High**	Major	**Moderate / Major**	Possible	Medium			
		Benthic Communities	High	Very High	**High**	Major	**Moderate / Major**	Possible	Medium			
		Fish & Shellfish	High	Very High	**High**	Major	**Moderate / Major**	Possible	Medium			
		Marine Protected Areas	Low	Very High	**Very High**	Negligible	**Negligible**	Possible	Low			

APPENDIX C:
Drill Cuttings Modelling

MAKING COMPLEX EASY

A TETRA TECH COMPANY

SERICA ENERGY - KYLA WELL

Drill Cuttings and Muds Dispersion Modelling



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REPORT

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EXECUTIVE SUMMARY

Project Background

Serica Energy Chinook Ltd (Serica) is planning to develop the Kyla oil field via a single subsea well located in United Kingdom Continental Shelf (UKCS) Block 29/2c in the Central North Sea, approximately 182 kilometres (km) to the southeast of Peterhead on the Scottish coastline. Serica holds 100% equity and operatorship of the Licence. The Kyla well will be tied-back to the Bittern Valve Skid then to Triton FPSO operated by Dana Petroleum UK Limited.

To support the environmental impact assessment (ES) for the Kyla Development, Serica commissioned RPS to undertake a detailed drill cuttings and muds dispersion modelling study to quantify the distribution of deposited cuttings and muds on the seabed and the total suspended solids (TSS) concentrations in the water column resulting from the proposed drilling and discharge program.

The purpose of the modelling is to provide an understanding of a conservative 'outer envelope' of the potential area of deposited cuttings and muds on the seabed and TSS concentrations (TSS) resulting from the proposed drilling and discharge program.

Methodology

The modelling study was conducted in stages. Firstly, 10-years of three-dimensional current data (2010–2019) for the study site was generated to represent the combined influence of ocean drift currents and tidal currents. Secondly, the current data and discharge characteristics were input into a three-dimensional sediment dispersion model, MUDMAP, to predict the movement and initial settlement of cuttings and drilling muds based on the proposed discharge program, which included 895 m^3 of cuttings and 365.1 m^3 of drilling muds solids being discharged to the marine environment. Thirdly, as the spud date can vary, 100 simulations were modelled with varying start dates to assess a range of current conditions for each release location. Results from the 100 simulations were overlayed to determine deposition on the seafloor, and maximum TSS concentrations based on acute (1-hr averaged concentration) and chronic (24-hr averaged concentration) exposure thresholds, in each grid cell.

Key Results

Deposition

- The maximum predicted thickness of deposited cuttings and muds was predominantly associated with the drilling of the 36- and 26-inch bores, which were returned directly to seafloor from a discharge height of 2 m above the seafloor. A maximum thickness of 0.57 m was predicted within 50 m of the discharge location.
- Based on the assessment of 100 simulations the maximum distances from the release location to the edge of the low exposure (10 mg/cm²/day [1.0 mm]) , moderate exposure (30 mg/cm²/day [3.0 mm]) and high exposure (100 mg/cm²/day [10.2 mm]) thresholds were 0.33 km, 0.15 km and 0.06 km, respectively. The total area of coverage for the low exposure threshold, or greater, was 0.12 km^2.

Acute (1-hr averaged concentrations) Total Suspended Solids Exposure

Based on the assessment of 100 simulations, the maximum distance from the release location to the edge of the low exposure TSS concentration threshold (10 mg/L) for acute exposure (1-hr averaged concentration) was 1.02 km. Additionally, the maximum distance from the release location to the edge of the moderate exposure TSS concentration threshold (50 mg/L) for acute exposure (1-hr averaged concentration) was 0.27 km. High exposure (100 mg/L) TSS concentrations did not exceed 0.27 km from the release location. The total area of coverage for the low exposure threshold, or greater, was 1.19 km^2.

Chronic (24-hr averaged concentrations) Total Suspended Solids Exposure

- The maximum distance from the release location to the edge of the low exposure TSS concentration threshold (5 mg/L) for chronic exposure (24-hr averaged concentration) was 0.41 km. Additionally, the maximum distance from the release location to the edge of the chronic moderate exposure TSS concentration threshold (15 mg/L) was 0.19 km. Chronic high exposure (50 mg/L) TSS did not exceed 0.08 km from the release location. The total area of coverage for the low exposure threshold was 0.16 km^2.
- The discharge of cuttings and muds will lead to relatively short-lived increased TSS concentrations of typically up to 24 hours, which are expected to dilute and reduce with distance from the release location to concentrations below the reporting thresholds. Based on the temporary elevated concentrations of TSS concentrations at the low exposure threshold, and the limited occurrence of the very localised high exposure, the impact likelihood is thus considered low.

1 INTRODUCTION

Serica Energy Chinook Ltd (Serica) is planning to develop the Kyla oil field via a single subsea well located in United Kingdom Continental Shelf (UKCS) Block 29/2c in the Central North Sea, approximately 182 kilometres (km) to the southeast of Peterhead on the Scottish coastline. Serica holds 100% equity and operatorship of the Licence.

To support the environmental impact assessment (ES) for the Kyla Development, Serica commissioned RPS to undertake a detailed drill cuttings and muds dispersion modelling study to quantify the distribution of deposited cuttings and muds on the seabed and the total suspended solids (TSS) concentrations in the water column resulting from the proposed drilling and discharge program.

The coordinates for the proposed Kyla well release location is presented in Table 1.1 and illustrated in Figure 1.1.

The purpose of the modelling is to provide an understanding of a conservative 'outer envelope' of the potential area of deposited cuttings and muds on the seabed and TSS concentrations (TSS) resulting from the proposed drilling and discharge program.

Modelling was performed using an advanced three-dimensional dispersion model; MUDMAP. The MUDMAP model calculates the transport, spreading, and deposition of discharged cuttings and muds solids over time, based on the prevailing current conditions, the proposed drilling and discharge program, and physical properties of the discharged cuttings and muds solids.

As the spud date may vary, 100 simulations were modelled with varying start dates to assess a range of current conditions.

Table 1.1 Coordinates for the drill cuttings and muds discharge modelling release location.

Well name	Latitude*	Longitude*	Water depth (m)
Kyla	56° 53' 1.1" N [6,305,250 N]	1° 13' 50.7" E [575,000 E]	91

*Datum: WGS84 [ED50 / TM 0 N]

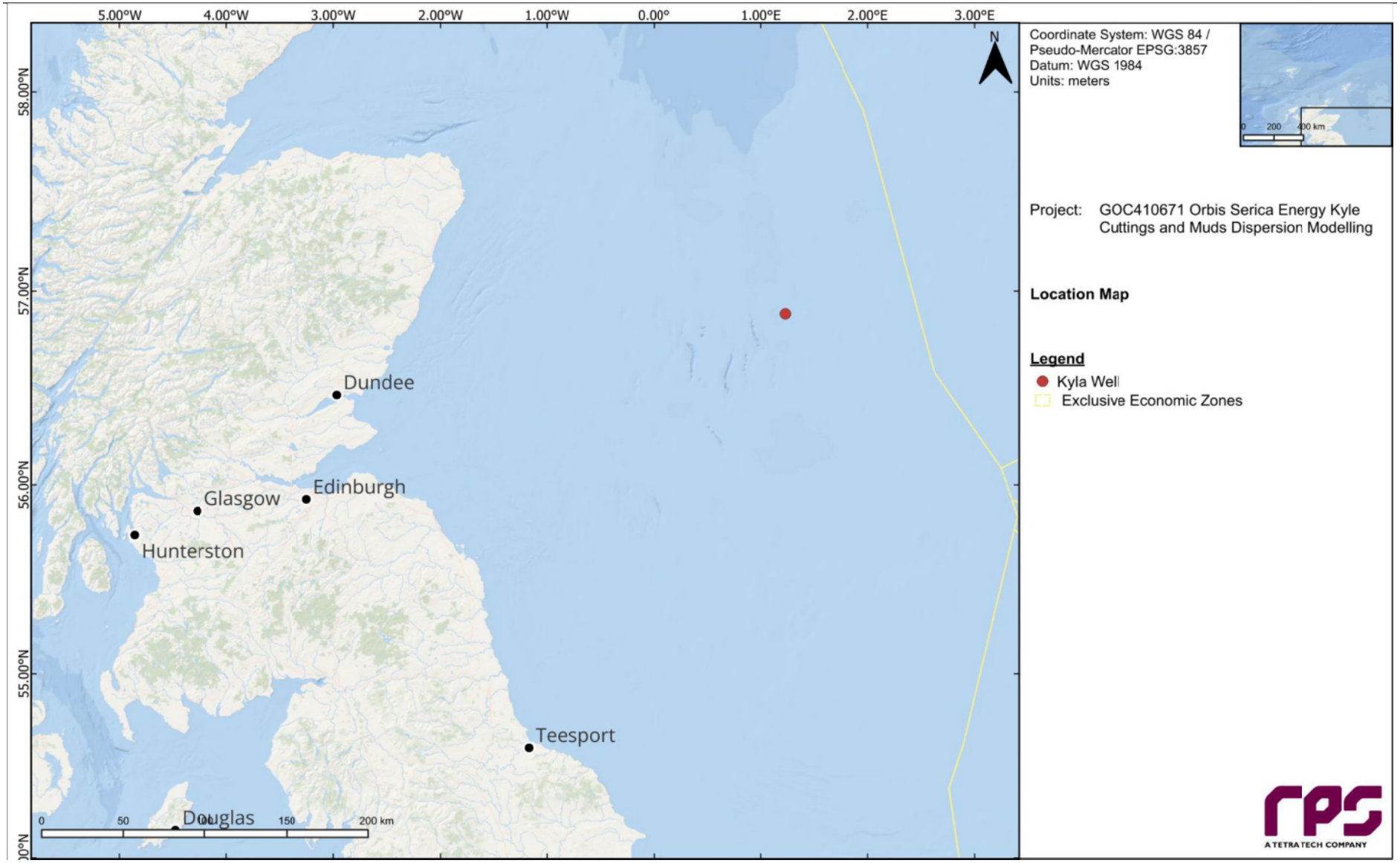


Figure 1.1 Drill cuttings and muds discharge modelling release location.

2 SCOPE OF WORK

The scope of work included the following components:

1. Ten years (2010 to 2019 (inclusive)) of current data were generated, which included the combined influence of ocean and tidal currents. The current data are suitably long enough to be indicative of interannual variability in ocean currents;

2. The current data and the defined discharge program specifics were input into the three-dimensional dispersion model (MUDMAP) with a total of 100 simulations modelled that included discharges at the seafloor and sea surface. Each simulation had different start times to ensure a range of current conditions were assessed;

3. Present example deterministic modelling results of the sea surface discharges for the drilling program; and

4. Results from the 100 simulations were overlayed to determine the maximum sediment deposition, and total TSS concentrations based on acute (1-hr averaged concentration) and chronic (24-hr averaged concentration) exposure thresholds, in each grid cell.

3 REGIONAL CURRENTS

The release location is located within the central region of the North Sea. The North Sea is a shallow sea that lies between Norway, the United Kingdom and the European Continent. Up to two thirds of the Sea is characterised by a depth shallower than 100 m. The Norwegian Trench being the one exception, with depths exceeding 700 m. This deep feature has a strong influence on the circulation within the North Sea.

The variability of the general circulation in the North Sea is determined by varying local wind conditions and their interaction with the inflow of Atlantic water masses through the northern and southern boundaries (Mathis et al., 2015). The warm and saline Atlantic waters enter the North Sea through the English Channel and northern boundary (Winther and Johannessen, 2006). Waters entering through the northern boundary can be divided into three different inflow sites; the Orkneys-Shetland section (Fair Isle Current), the Shetland shelf area and the western section of the Norwegian Trench.

General circulation patterns in the North Sea are predominantly cyclonic (Winther and Johannessen, 2006). The Atlantic water flow entering the North Sea is primarily southward and is steered by the local topography. Southern flows adjacent to the Norwegian mainland then proceed eastward through Skagerrak, the strait running between the Jutland peninsula of Denmark, the east coast of Norway and the west coast of Sweden, connecting the North Sea and the Kattegat Sea. This flow continues eastward, and when it reaches the inner part of Skagerrak, the area between Denmark, Sweden and Norway, it meets brackish water from the Baltic Sea and turns northward (Winther and Johannessen, 2006). This current follows the Norwegian coast west and then north and becomes the Norwegian Coastal Current.

Figure 3.1 presents a schematic of the regional currents in the North Sea.

Readers are referred to Lee (1980), Huthnance (1991) and Mathis et al., (2015) for detailed reviews of the physical oceanography of the North Sea.

To accurately describe the variability in currents both horizontally and vertically, data based on the combination of ocean currents and tides were included as part of this study. Below is a summary of the combined datasets.

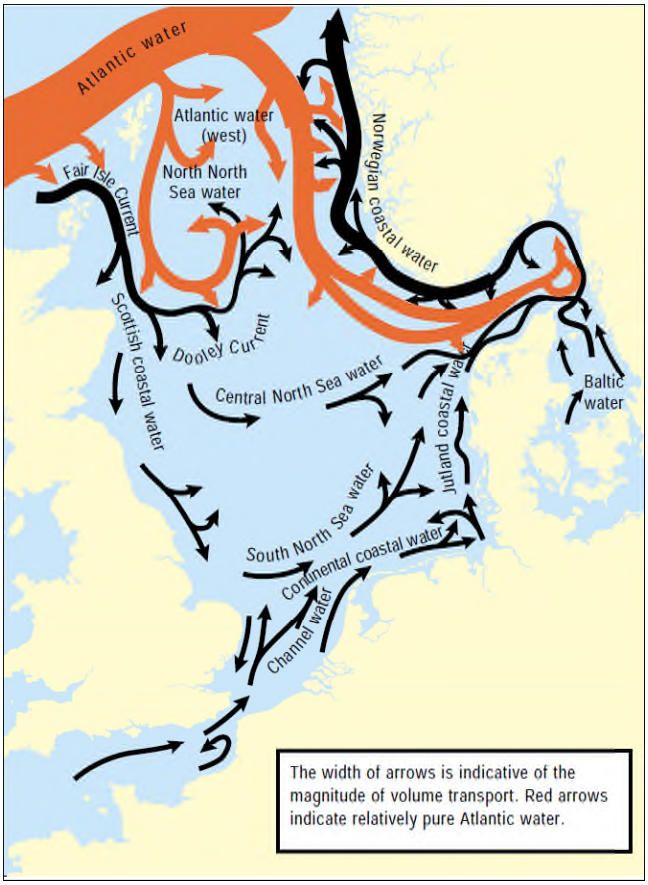


Figure 3.1 Schematic showing the oceanic current circulation in the study region (Image source: OSPAR, 2000).

3.1 Tidal currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world for over 35 years (Isaji and Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003; Makarynskyy et al., 2010), whilst being used for a wide variety of disciplines within marine environments (e.g. Zigic et al., 2003, 2009; Talouli et al., 2009; King et al., 2010; Makarynskyy et al., 2010; 2015). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

RPS has a seamless global tidal model. The tidal domains are sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grid cells are allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over regions with more complex bathymetry. Figure 3.2 shows a zoomed in image of the North Atlantic Ocean and North Sea model regions.

A combination of datasets was used to describe the shape of the seabed within the high-resolution grid. Depths for the region were extracted from nautical charts and the SRTM30_PLUS dataset (see Becker et al., 2009), which provides a 30-arc second, or approximately 1 km, resolution.

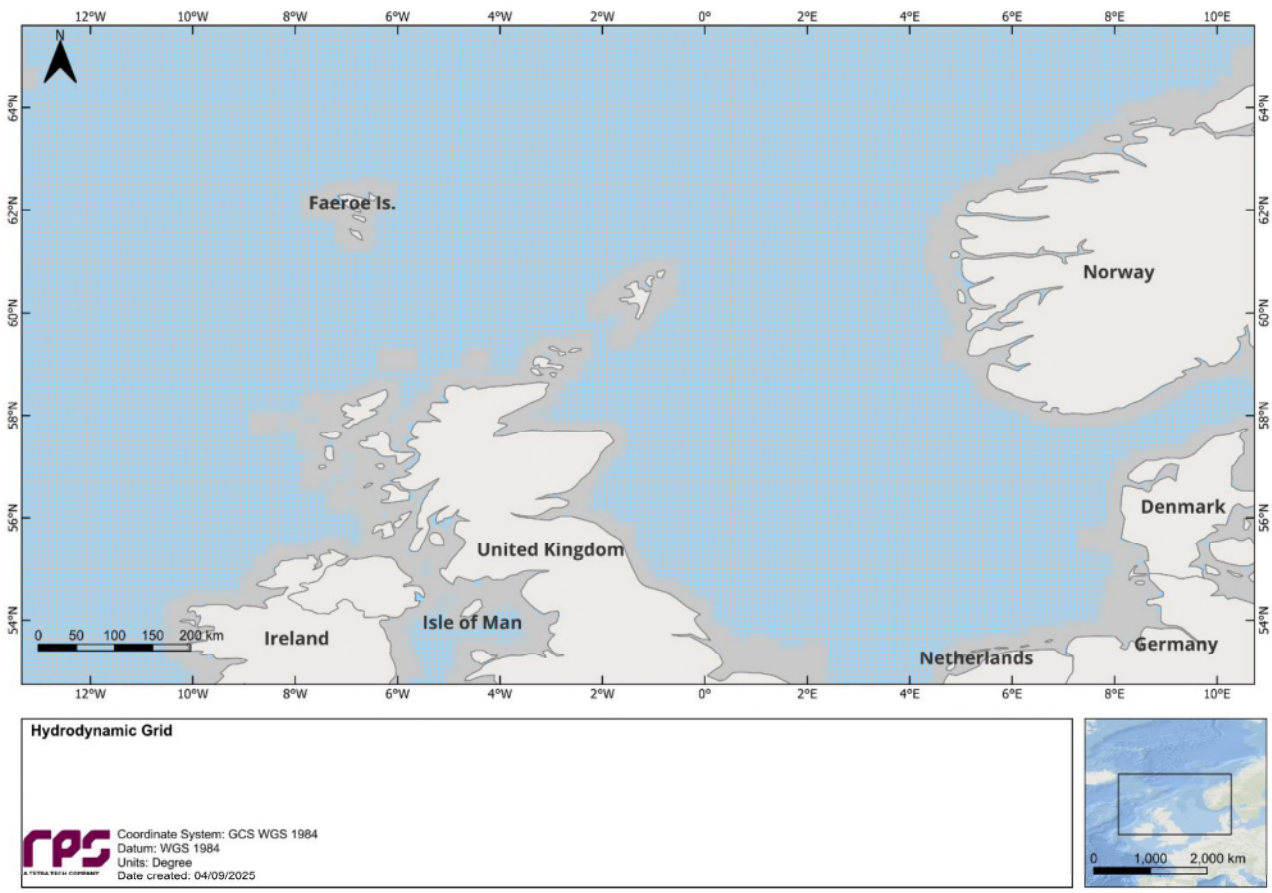


Figure 3.2 Map showing the regions of sub-gridding for the study area and example nearshore resolution.

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 8.0) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, time series surface heights were calculated along the open boundaries for the simulation period.

The Topex/Poseidon satellite data has a resolution of 0.25 degrees globally, with higher resolution in coastal regions, and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The data capturing satellites, equipped with two altimeters capable of taking sea level measurements accurate to less than ± 5 cm, measured oceanic surface elevations (and the resultant tides) for the period 1992–2005. In total these satellites carried out 62,000 orbits of the planet. The Topex-Poseidon tidal data has been widely used amongst the oceanographic community, being referenced in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). The Topex/Poseidon tidal data is considered suitably accurate for this study.

3.2 Ocean Currents

Data describing the flow of ocean currents were for the years 2010 to 2019 (inclusive) obtained from HYCOM (Hybrid Coordinate Ocean Model) (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of every 3 hours. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

The HYCOM model has been extensively documented through many publications which are available online[1]. The HYCOM data have also been used within the North Sea region for various application (e.g., Melsom, 2005; Winther and Johannessen, 2006; Winther and Evensen, 2006; Akinbamini et al., 2022).

For this study, the HYCOM hindcast currents were obtained for the year 2010-2019. Figure 3.3 provides an example of the modelled surface ocean currents (HYCOM) for the region.

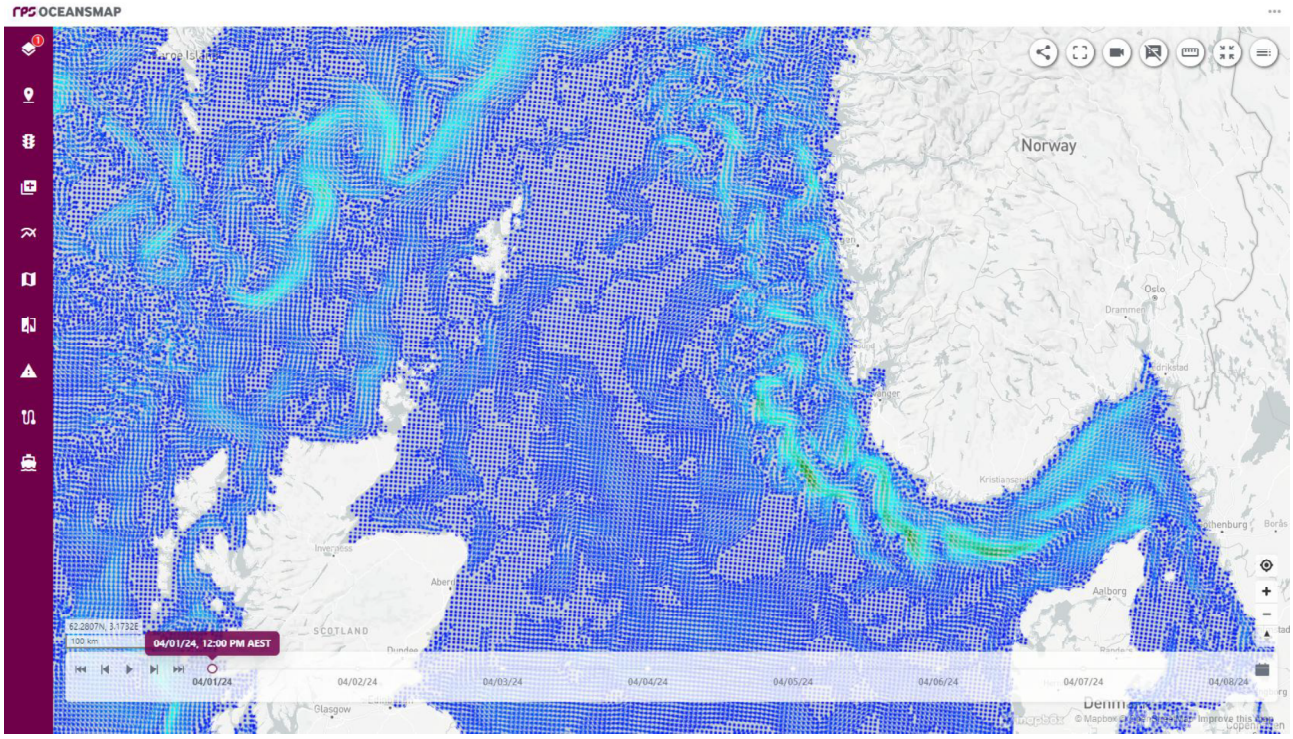


Figure 3.3 Snapshot example of the predicted HYCOM ocean surface currents in the region. Colour and size of individual arrows indicate current speed (m/s).

[1] https://hycom.org/publications

3.3 Surface and Near-Bottom Currents Nearby the Release Location

Figure 3.4 and Figure 3.5 present the monthly surface and near-bottom current roses nearby the release location, respectively. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.05 m/s and 0.1 m/s are predominantly used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

Table 3.1 and Table 3.2 present the surface and near-bottom monthly current speeds and directions nearby the release location, respectively.

The monthly average surface current speeds ranged from 0.21 m/s (June) to 0.24 m/s (January and December). Additionally, the monthly maximums reached speeds ranging between 0.63 m/s (April) and 1.01 m/s (December; Table 3.1). The surface current directions were generally consistent with currents typically flowing along the east-northeast and south-southwest axis (Figure 3.4).

In comparison, the monthly average near-bottom current speeds were relatively consistent ranging from 0.19 m/s (February, April, June and November)0.20 m/s (January, March, July to October and December), whilst near-bottom monthly maximum current speeds ranged between 0.56 m/s (May) and 0.76 m/s (August; Table 3.2). Additionally, the near-bottom current direction predominantly occurred along the east-northeast and south-southwest axis (Figure 3.5).

Table 3.1 Monthly average and maximum surface current speeds nearby the release location. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2010-2019.

Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction(s) (Towards)
January	0.24	0.92	East-northeast and South-southwest axis
February	0.23	0.94	
March	0.23	0.69	
April	0.22	0.63	
May	0.22	0.80	
June	0.21	0.74	
July	0.22	0.74	
August	0.22	0.82	
September	0.22	0.76	
October	0.23	0.72	
November	0.23	0.76	
December	0.24	1.01	
Minimum	**0.21**	**0.63**	-
Maximum	**0.24**	**1.01**	

Table 3.2 Monthly average and maximum near-bottom current speeds nearby the release location. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2010-2019.

Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction(s) (Towards)
January	0.20	0.62	East-northeast and South-southwest axis
February	0.19	0.62	
March	0.20	0.61	
April	0.19	0.61	
May	0.20	0.56	
June	0.19	0.61	
July	0.20	0.58	
August	0.20	0.76	
September	0.20	0.62	
October	0.20	0.65	
November	0.19	0.57	
December	0.20	0.71	
Minimum	**0.19**	**0.56**	-
Maximum	**0.20**	**0.76**	

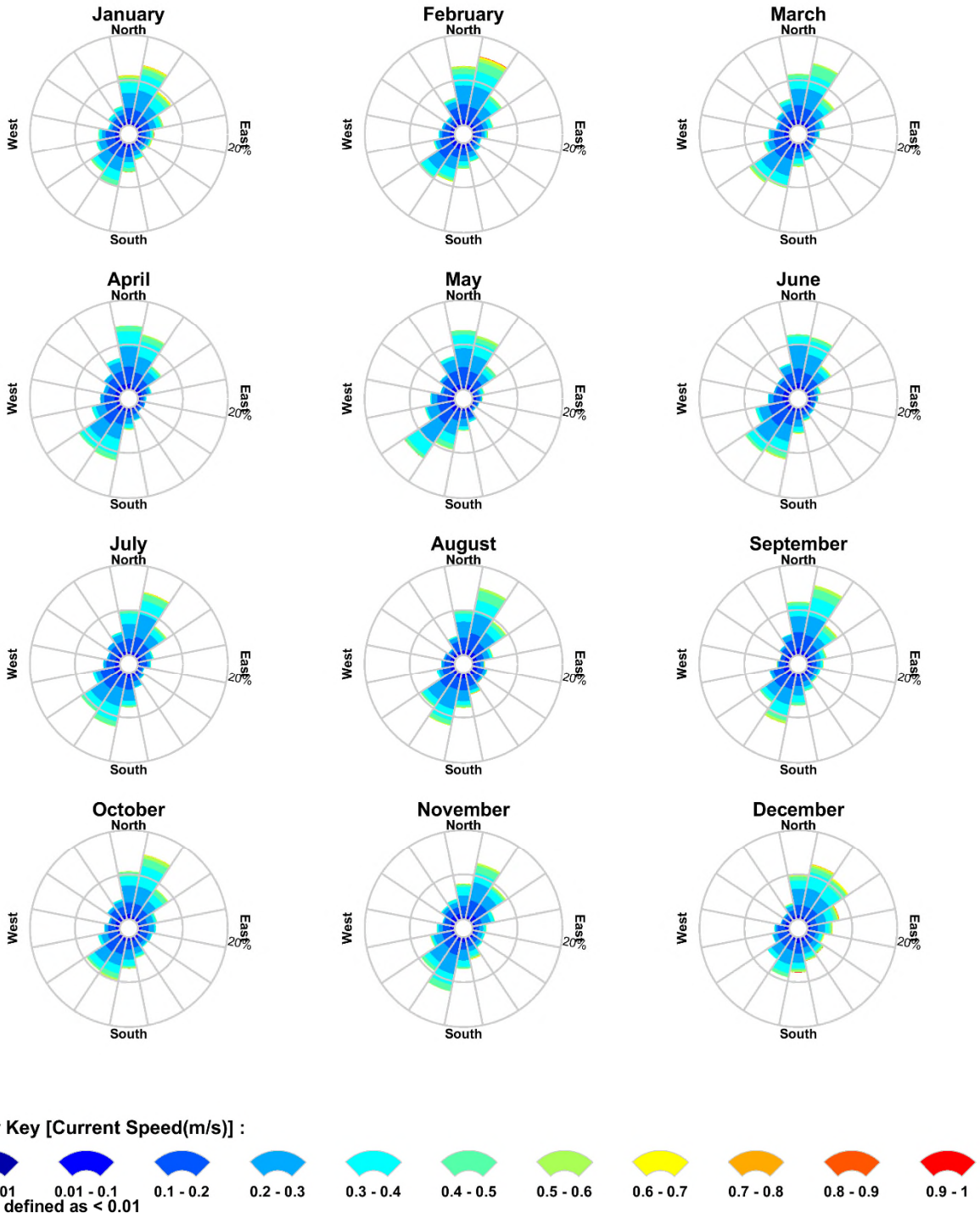


Figure 3.4 Monthly surface current rose distributions nearby the release location, derived from the 2010 to 2019 modelled dataset.

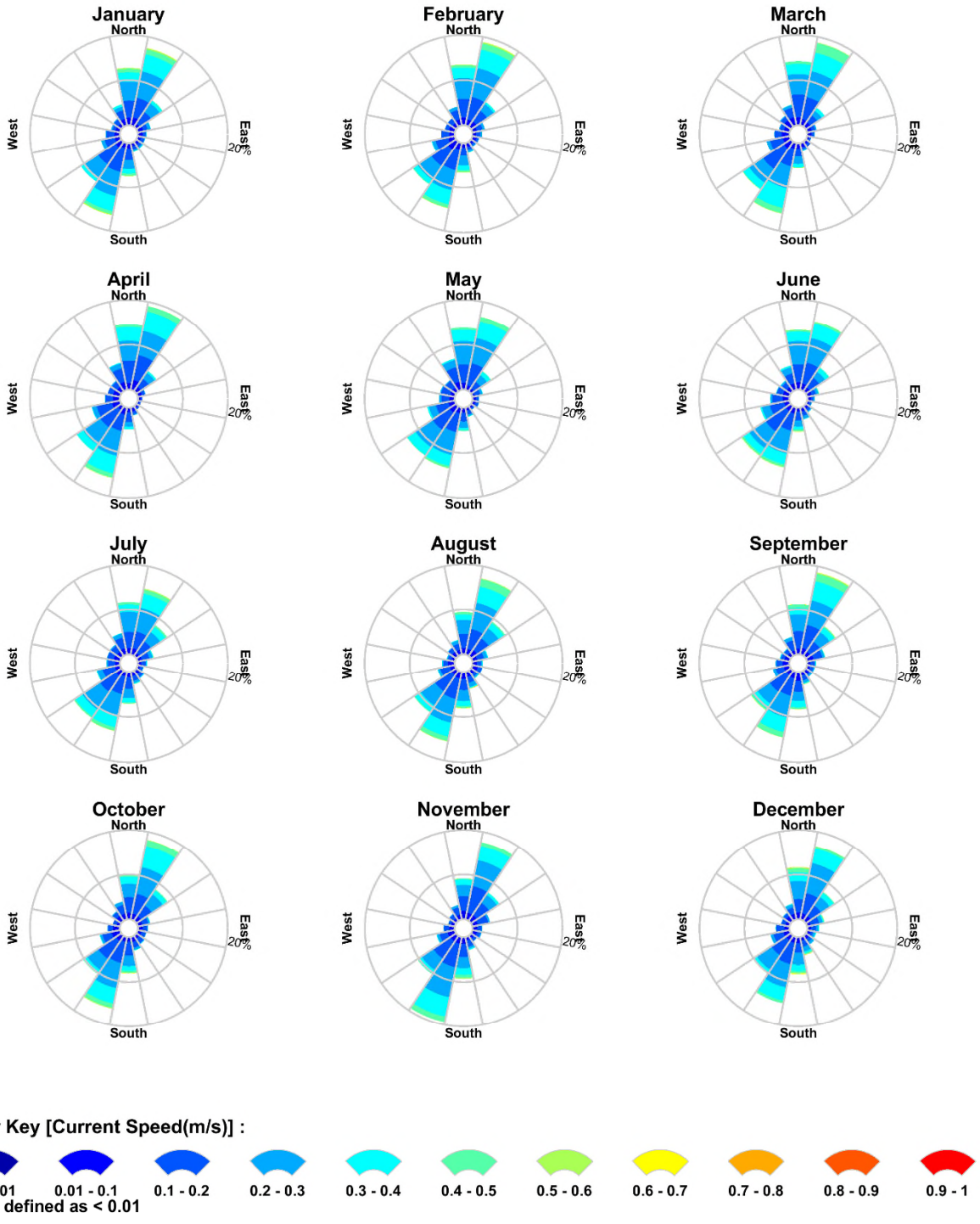


Figure 3.5 Monthly near-bottom current rose distributions nearby the release location, derived from the 2010 to 2019 modelled dataset.

4 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release location were obtained from the HYCOM dataset (see Section 3.2).

The three-dimensional salinity and temperature datasets are used in the model domain to inform water density in through the water column layers.

Table 4.1 presents the monthly average sea temperature and salinity of the surface and near-bottom layers nearby the release location. Monthly average surface water temperature ranged from 6.4°C (March) to 15.4°C (August). In contrast, near-bottom waters ranged from 6.4°C (March and April) to 8.2°C (January). Salinity remained relatively consistent through the water column ranging between 34.8 psu to 35.0 psu.

Figure 4.1 presents depth profiles of water temperature and salinity nearby the release location.

Table 4.1 Monthly average sea surface temperature and salinity nearby the release location.

Month	Temperature (°C)		Salinity (psu)	
	Surface	Near-bottom	Surface	Near-bottom
January	8.2	8.2	35.0	35.0
February	7.0	7.0	35.0	35.0
March	6.4	6.4	35.0	35.0
April	7.0	6.4	35.0	35.0
May	9.5	6.5	35.0	35.0
June	12.1	6.6	35.0	35.0
July	14.5	6.9	34.9	35.0
August	15.4	6.8	34.8	35.0
September	13.6	6.9	34.8	34.9
October	11.6	7.3	34.8	35.0
November	9.0	7.7	34.9	34.9
December	7.5	7.5	35.0	35.0
Minimum	**6.4**	**6.4**	**34.8**	**34.9**
Maximum	**15.4**	**8.2**	**35.0**	**35.0**

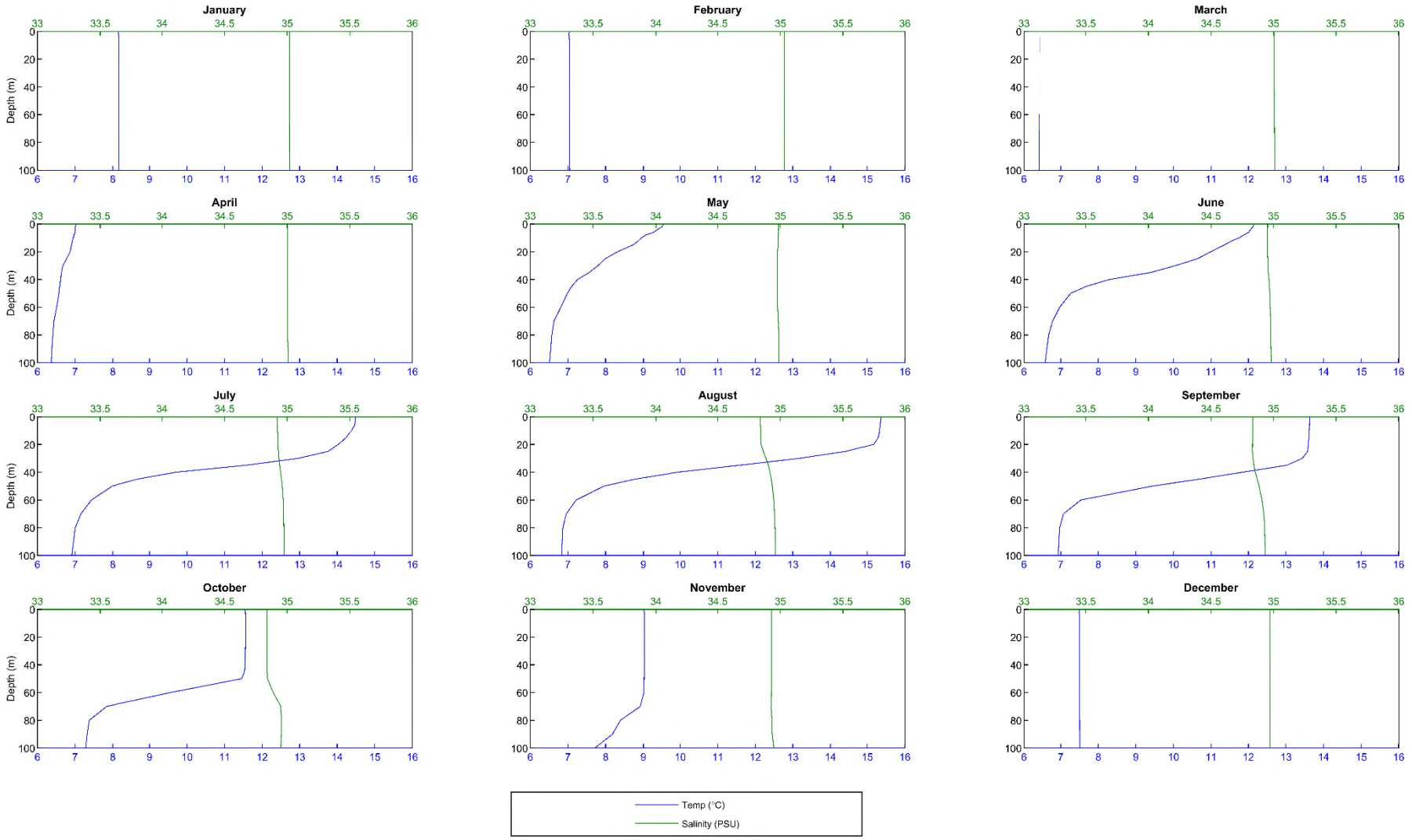


Figure 4.1 Monthly average depth profiles of water temperature and salinity nearby the release location.

5 SEDIMENT DISPERSION MODELLING

5.1 Sediment Dispersion Model Description – MUDMAP

MUDMAP is a three-dimensional plume model used by industry and regulators to aid in assessing the potential environmental effects from operational discharges such as drill cuttings, drilling fluids (muds) and produced water. The model has been applied to hundreds of assessments in over 35 countries.

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. The model predicts the dynamics of the discharge material and resulting seabed concentrations and bottom thicknesses over the near-field (i.e. the immediate area of the discharge) and the far-field (the wider region). Figure 5.1 shows a conceptual diagram of the dispersion and fates of drill cuttings and muds discharge to the ocean and an idealized representation of the three discharge phases.

Settling under currents is selective for particle size, with the larger particles (rock chips to sand) tending to settle quickly, forming a pile that aligns with the predominant current axis. Smaller particles (especially silts and clays) will remain suspended for longer periods and will therefore be dispersed more widely by the ambient current conditions. Dispersion of the finer discharged material will tend to be enhanced with increased current speeds and water depth and with greater variation in current direction over time and depth.

Along with the advanced analyses tools, MUDMAP can simulate six classes of material (or 36 sub-categories), each with unique density and particle-size distribution. During the dispersion stage, the model particles are transported in three-dimensions according to the current data and horizontal and vertical mixing coefficients at each time step according to the governing equations.

MUDMAP has been extensively reported, validated and applied for discharge operations (e.g. Burns et. al., 1999; King and McAllister, 1997, 1998; Spaulding, 1994; Albert and Prosser, 2023).

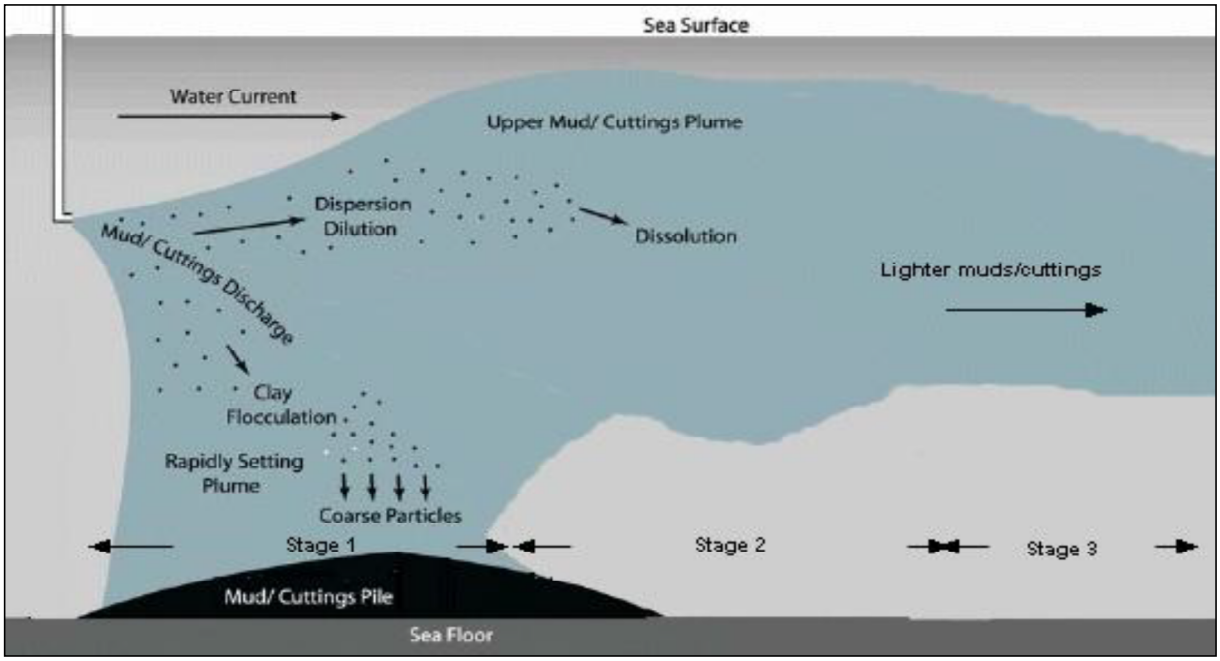


Figure 5.1 Conceptual diagram showing the general behaviour of cuttings and muds following the discharge to the ocean (Neff, 2005) and the idealised representation of the three discharge phases.

5.2 Drilling and Discharge Program

Serica has indicated that a conventional drilling design will be used for the proposed drilling program. The following is the description of the proposed drilling and discharge.

Table 5.1 presents a summary of the estimated discharge of volume of drill cuttings and unrecoverable mud solids for the proposed drilling and discharge program. To account for any unforeseen mechanical or geological issues, a re-spud scenario and contingency sidetrack have been added to the well profile to represent a worst-case scenario.

Drilling of the well will commence with a 36" bore diameter well interval followed by a 26" bore diameter well interval and may require a re-spud scenario. Both well intervals will be drilled using seawater sweeps with the cuttings being returned (discharged) directly to the seafloor (riser-less discharge) over 0.78 days and 4.88 days for the 36" and 26" bore well intervals, respectively.

Following the near-seabed discharge, 17.5", 17.5" sidetrack, 12.25" (PH), 12.25 (Dev) and 9.5" bore diameter well intervals will be drilled using low-toxicity oil-based muds (LTOBM) which, for the purposes of this study, are assumed to be thermally processed (involving a milling process) on the mobile offshore drilling unit and returned to the sea surface. The cuttings and muds will be discharged from a vertically orientated pipe over 20.74 days (Table 5.1).

Note, the cuttings powder discharged by thermal processing have <1% oil on cuttings (OOC) which complies with Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) hydrocarbon discharge requirements (~0.06% OOC). The milled cuttings and muds solids would be dispersed in the water column and are highly unlikely to form piles on the seabed.

The anticipated total discharge duration per well is 26.4 days.

Table 5.1 Summary of the estimated discharge of volume of drill cuttings and unrecoverable mud solids for each well interval.

Bore Diameter (inches)	Discharge method	Volume of cuttings solids (m^3)	Fluid Type	Volume of muds liquid and solids (m^3)	Volume of solids in the muds (m^3)	Discharge Duration (days)
36	Returned directly to seabed	30	Seawater sweeps	125	12.5	0.39
36 (re-spud)		30		125	12.5	0.39
26		185		670	67	2.44
26 (re-spud)		185		670	67	2.44
17.5	Cuttings and drilling fluid brought to MODU and discharged to the sea surface	105	LTOBM	341	34.1	2.48
17.5 (sidetrack)		105		341	34.1	2.48
12.25 (PH)		107		449	44.9	4.73
12.25 (Dev)		100		441	44.1	5.20
9.5		48		489	48.9	5.85
Total		**895**		**3,651**	**365.1**	**26.4**

5.3 Discharge Input Data

The input data used to setup the dispersion model included:

- Volume and discharge duration of the cuttings and unrecovered muds solids;
- Particle size distributions (PSD) and associated settling velocities of discharged cuttings and unrecoverable muds solids;
- Bulk density of the discharged cuttings and unrecoverable muds solids;
- Temperature and salinity profile of the receiving waters;
- The size and orientation of the discharge pipe;
- The height/depth of the discharge point relative to mean sea level; and
- Depth-varying current data to represent local physical forcing.

Table 5.2 provides a summary of the discharge configuration and the estimated volume of cuttings and muds solids input into the discharge model. Simulations were run for an additional period after the completed discharges to allow sediments to disperse through the water column and potentially deposit on the seafloor (see Table 5.2).

Table 5.2 Input data used for the drill cuttings and muds modelling.

Parameter/description	Kyla
Total volume of cuttings discharged (m^3)	895
Total volume of muds solids discharged (m^3)	365.1
Discharge duration (days) [model duration]	26.4 [29]
Depth of surface discharge (m)	0 (sea surface)
Height of riserless discharge above seafloor (m)	2
Water depth (m)	91
Discharge pipe orientation	Vertically downwards
Number of simulations	100 (randomly selected start simulation dates and times between 2010–2019, inclusive)
Seasonal or Annual assessment	Annual

It is anticipated that well intervals will be drilled using a conventional drilling approach. Model input included particle sizes for cuttings and drilling muds returned to the seafloor varying in diameter between 0.016 mm and 6 mm (Table 5.3). The PSD is representative of data previously used for well intervals drilled using WBM (e.g. Koh & Teh, 2011; IOGP, 2016). The PSD are based on the relative contribution of cuttings and drilling muds discharge volumes. Furthermore, it is assumed that cuttings and LTOBM from the 17.5” to 9.5” well diameter intervals will undergo thermal processing that includes a milling component on the MODU based on Rotomill technology (TWMA, 2024a). Particle sizes and percentage distributions used as model input are reflective of PSD analysis data presented by TWMA (2024b) and are presented in Table 5.4.

It is important to note that grain size has a greater influence on the rate of settling than density (Neff, 2005). The fall velocities for the various size classes were derived from empirical data provided by Dyer (1986).

Table 5.3 Cuttings and muds sediment grain sizes, settling velocities and percentage distributions applicable for each release location.

Class	Grain size (mm)	Settling velocity (cm/s)	Percentage Distributions
Medium cuttings	6	53.62	8.6
	5	49.46	8.6
	2	28.55	8.6
	1	12.73	5.8
	0.5	7.5	5.8
	0.45	6.6	2.9
Light cuttings	0.4	6	2.9
	0.35	5	2.8
	0.3	4	2.8
	0.25	3.1	2.8
	0.2	2.3	2.8
	0.15	1.6	2.8
Very light cuttings	0.1	0.8	2.8
	0.05	0.22	2.8
	0.04	0.15	2.9
	0.03	0.08	2.9
	0.02	0.04	2.9
Drilling mud solids	0.063	0.34	0.4
	0.05	0.22	1.6
	0.035	0.11	3.7
	0.026	0.06	6
	0.02	0.038	7.4
	0.016	0.026	9.4

Table 5.4 Thermal processed cuttings and muds sediment grain sizes, settling velocities and percentage distributions.

Class	Grain size (mm)	Settling velocity (cm/s)	Percentage Distributions
low-toxicity oil-based mud	0.15	1.6	8
	0.063	0.34	10
	0.04	0.15	7
	0.03	0.08	10
	0.02	0.038	5
	0.016	0.026	60

5.4 Grid Configuration

A grid covering a 50 km (longitude, x-direction) by 50 km (latitude, y-direction) region with varying depths was employed. The grid consisted of cells with a horizontal resolution of 50 m to calculate the deposition of drill cuttings and muds on the seabed and a vertical resolution of 10 m to estimate the TSS concentrations.

5.5 Mixing Parameters

The horizontal and vertical dispersion coefficients are used in dispersion modelling to represent the mixing and diffusion processes caused by turbulence, which are sub-grid processes at the scale of the hydrodynamic model drivers. The dispersion coefficients are expressed in units of rate of area change (m^2/s). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations. Increasing the vertical dispersion coefficient spreads the discharge further across the vertical layers.

The horizontal turbulent diffusion of the plume is dependent on the hydrodynamic conditions (i.e. wind, wave and current) and the physical scale of the plume compared to the scales of the oceanic processes that disperse the plume. For a plume of approximately 10-100 m width, dispersion occurs primarily through small-scale horizontal swirling motions and vertical mixing, with a horizontal dispersion rate of the order of 0.1 m^2/s. As the plume grows to a scale of 1-10 km, it begins to be subject to mesoscale eddies and horizontal dispersion rate becomes of the order of a few to tens m^2/s.

A horizontal coefficient value of 0.25 m^2/s was used to account for the turbulence as the discharged solids are transported from the release location for the near-bottom discharges. Additionally for the near-bottom discharges a low vertical coefficient value was employed (0.0001 m^2/s). In comparison, sea surface discharges employed horizontal and vertical coefficients of 1.0 m^2/s and 0.001 m^2/s, respectively.

5.6 Reporting Thresholds

The MUDMAP model is capable of predicting sediment deposition and TSS concentrations at levels below ecological relevance. To ensure that model results are both meaningful and interpretable, carefully selected thresholds for reporting are applied. Among the various sensitive marine ecosystems affected by sediment and turbidity stress, corals are recognised as the most vulnerable. Although cold-water corals have not been recorded in this area of the North Sea, by applying thresholds based on coral responses, this assessment adopts a worst-case conservative benchmark that ensures the protection of the most sensitive ecosystem components.

5.6.1 Deposition

Sediment impact is usually assessed by total sedimentation rate (mass of sediment settling per unit area per day), deposition thickness, or both.

Coral species vary widely regarding their tolerance to sediment deposition, ranging from less than 10 $mg/cm^2/day$ to over 400 $mg/cm^2/day$ (Erftemeijer et al., 2012). A conservative low exposure threshold of 10 $mg/cm^2/day$ has been applied for this study (see Table 5.5). Sustained high sedimentation rates of 30 $mg/cm^2/day$ (Hodgson, 1990; Browne et al., 2015) and above 100 $mg/cm^2/day$ over several weeks can lead to coral smothering, tissue necrosis, and long-term declines in coral cover (MScience, 2011). These impacts result from multiple interacting stressors, including the physical burden of sediments, shading and light limitation, and nutrient and contaminant loads associated with suspended material (Fabricius, 2005).

Accordingly, moderate and high exposure thresholds are set at ≥30 $mg/cm^2/day$ and ≥100 $mg/cm^2/day$, respectively, as shown in Table 5.5.

Equivalent sediment thicknesses were calculated based on the anticipated total discharge period of 26.4 days and an assumed in-situ bulk density of 2,600 kg/m^3. The low exposure threshold of 10 $mg/cm^2/day$ corresponds to approximately 1.0 mm of sediment accumulation over this period. Additionally, moderate and

high exposure thickness thresholds would equate to 3.0 mm to 10.2 mm, respectively. These align with literature findings such as Gilmour (2002), who observed that older corals suffer injury from 2 mm sediment layers applied every two days, with larger polyps showing damage at 5 mm and 10 mm sediment layers. Mesocosm experiments by Trannum et al. (2010) showed that cuttings layers as thin as 3 mm cause gradual community declines over six months in soft-sediment communities.

Table 5.5 Reporting thresholds for sediment deposition for the drill cuttings and unrecoverable muds discharge modelling for the 26.4-day drilling operation.

Impact level	Sedimentation rates (mg/cm²/day)	Equivalent sediment bottom thickness thresholds (mm)^	Notes/Comments
No Impact	<10	–	No measurable effect; natural sediment fluxes tolerated
Low Exposure	10	1.0	Minor effects; some sediment accumulation but corals tolerate
Moderate Exposure	30	3.0	Sub-lethal effects; reduced larval settlement (Babcock & Davies 1991), tissue stress
High Exposure	>100	>10.2	Smothering, mortality risk; long-term coral cover decline

^ Based on anticipated total discharge duration of 26.4 days and assuming final settled in-situ bulk density of 2,600 kg/m^3

5.6.2 TSS Concentration

A fundamental principle in assessing turbidity effects is the relationship between intensity (or TSS concentrations) and duration of exposure (Figure 5.2). High concentrations over a short duration may cause immediate stress or mortality, while prolonged exposures at lower concentrations can generate similar cumulative impacts. To address this relationship, TSS thresholds are expressed using both 1-hour averages (representing acute exposure) and 24-hour averages (representing chronic exposure).

The durations used here are intentionally conservative compared to those reported in experimental studies. Typically, acute effects are measured over periods of 1 to 7 days, while chronic effects are assessed over weeks to months (Brown et al., 2015; Stump et al., 2019). By comparison, this assessment adopts durations of just 1 hour (acute) and 24 hours (chronic), which is more appropriate given the operational context of drill cuttings and mud discharges, where TSS levels can rise sharply within minutes to days, significantly exceeding background levels. By applying shorter durations, the thresholds remain protective and precautionary.

In pristine offshore environments, background TSS levels are typically less than 10 mg/L, whereas naturally turbid nearshore reefs can experience levels exceeding 100 mg/L (Erftemeijer et al., 2012). Studies have shown that short-term spikes between 50 and 100 mg/L can cause acute sub-lethal stress, such as increased mucus production and reduced photosynthesis (Browne et al., 2015; Stump et al., 2019). Chronic exposures between 15 to 50 mg/L are linked to long-term physiological impairment, reduced reproductive success and higher mortality rates (Browne et al., 2015; Erftemeijer et al., 2012). The final reporting TSS thresholds are presented in Table 5.6.

Table 5.6 Reporting thresholds for TSS concentrations for the drill cuttings and unrecoverable muds discharge modelling.

Impact level	Acute Exposure (1-hour averaged concentration) (mg/L)	Chronic Exposure (24-hour averaged concentration) (mg/L)	Notes/Comments
No Impact	<10	<5	Background or natural variability; corals tolerate well
Low Exposure	10	5	Minor physiological stress; corals acclimate to short pulses
Moderate Exposure	50	15	Sub-lethal effects; mucus production, reduced photosynthesis
High Exposure	> 100	> 50	Tissue damage, mortality risk; chronic exposure particularly harmful

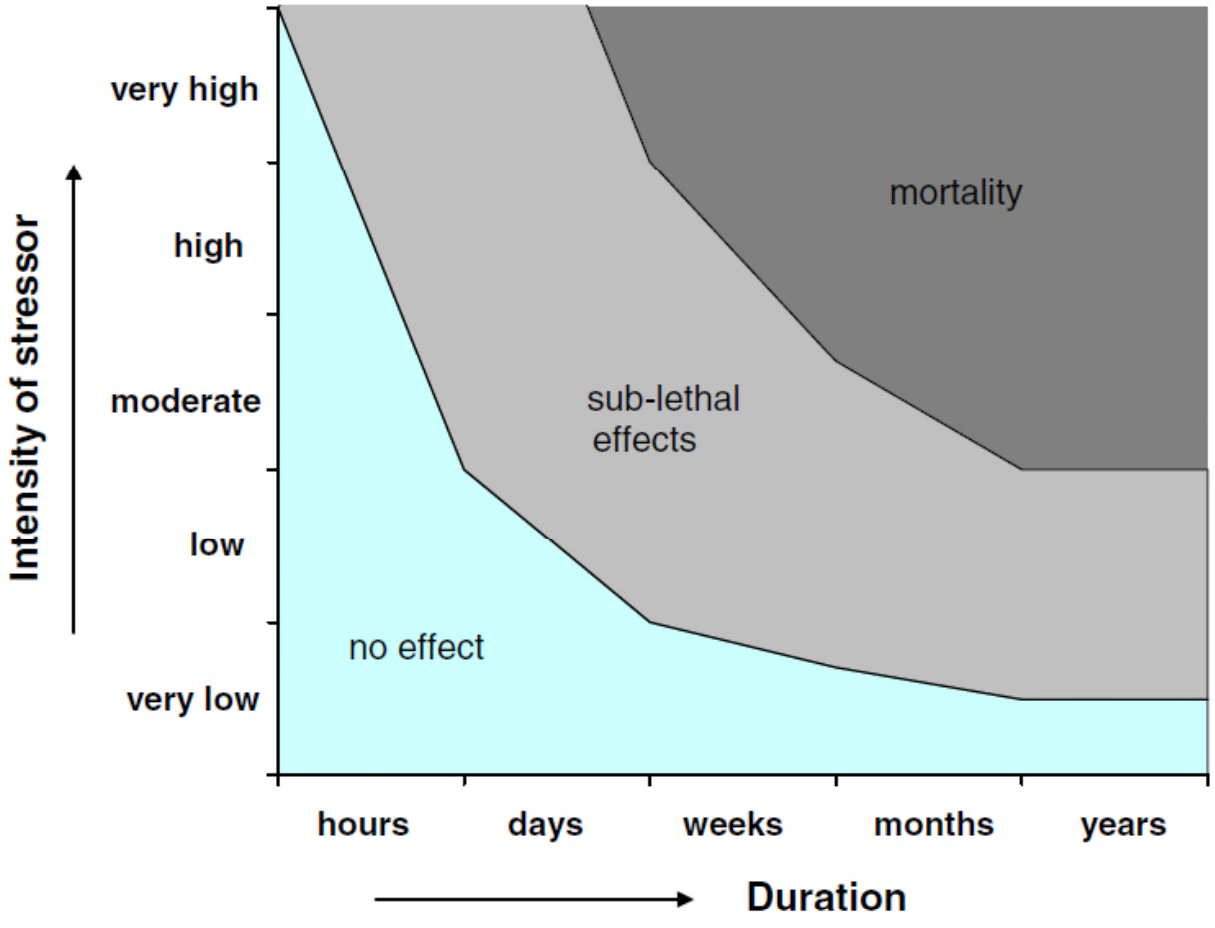


Figure 5.2 Conceptual relationship between the intensity and duration of a stress event and the risk of sublethal and lethal effects on corals. The figure illustrates the general relationship between the magnitude of an increase in turbidity or sedimentation above background levels (vertical axis), how long it lasts (horizontal axis) and the onset of effects on corals (Source: Erftemeijer et al., 2012).

5.7 Analysis of Output

During each individual simulation the MUDMAP model recorded the final mass on the seafloor in each grid cell over the entire model domain. Once all simulations were complete all model outputs were compared to determine the maximum deposition that occurred in each grid cell across all of the runs.

Additionally, during each simulation a timeseries of the TSS concentrations through the water column were recorded at 5-minute intervals within each grid cell. This time series was used to calculate the highest 1-hour moving averaged (acute exposure) and 24-hour moving averaged (chronic exposure) TSS concentrations for the simulation. Thereafter, once all the simulations were run, the moving averages from each individual simulation were compared to determine the maximum acute and chronic exposure concentrations.

It's important to note that the reported TSS concentrations are above background TTS concentrations.

6 Results

6.1 Deterministic Modelling Results

Deterministic modelling (single simulation) results of the near-seabed and near-sea surface discharges for the drilling and discharge program are presented below.

6.1.1 Deposition

Figure 6.1 and Figure 6.2 present model screenshots of the sedimentation rate during the modelled drilling and discharge operation during the near-seabed discharges from a single simulation. The sedimentation rate during the near-surface discharges for the single simulations did not exceed the low exposure threshold of 10 mg/cm²/day, as such no figures are presented.

The model screenshots illustrate the evolution of the deposition. These images have been included to provide an example "snapshot" of the predicted orientation and size of depositional footprint influenced by the time-varying current directions and speeds.

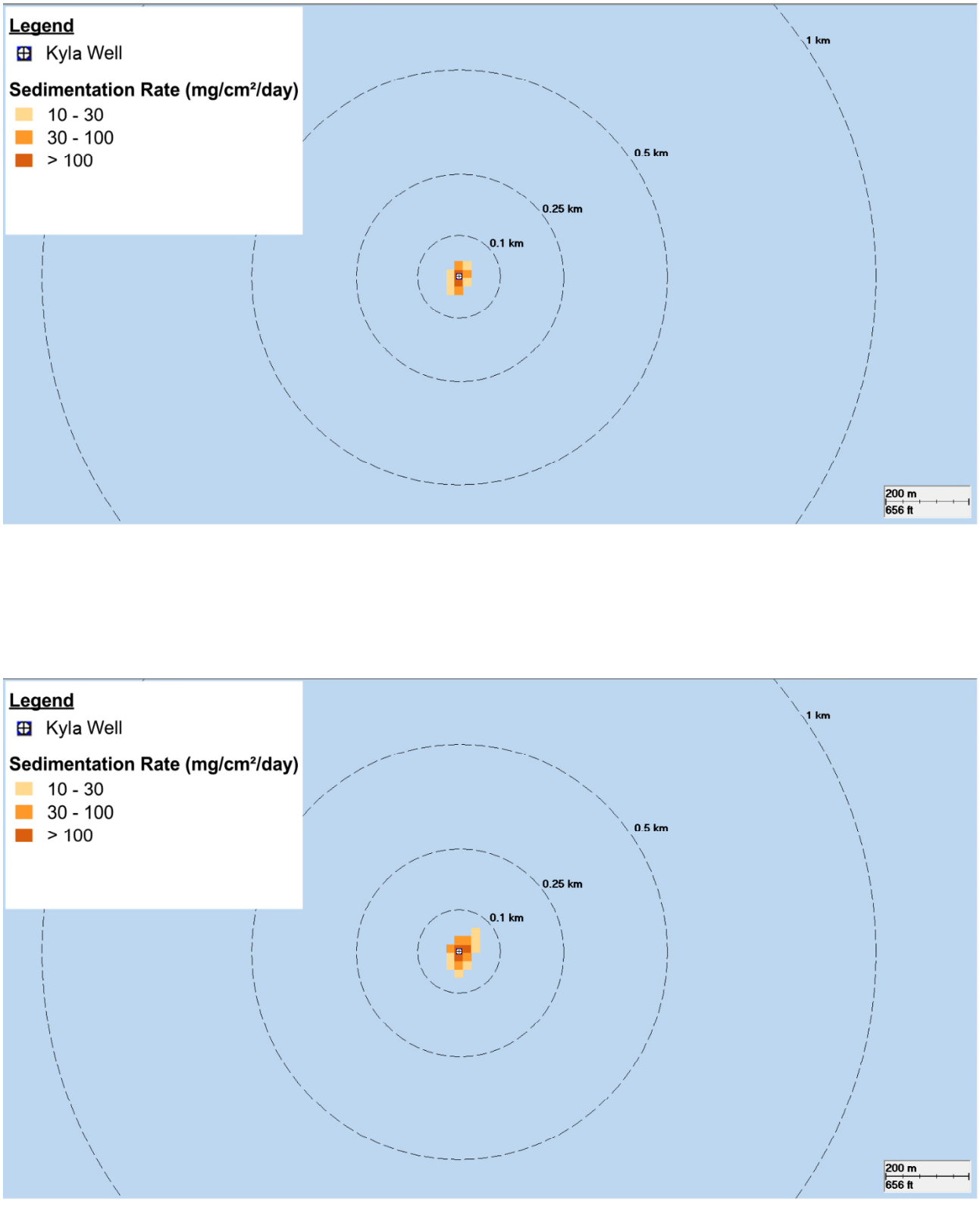


Figure 6.1 **Example plan-view screenshots of the predicted sedimentation rate (in each grid cell) 24 hours (top image) and 48 hours (bottom image) after the commencement of the near-seabed discharges of drilling cuttings and muds. Screenshot results are from 1 simulation of the 100 modelled as part of the study.**

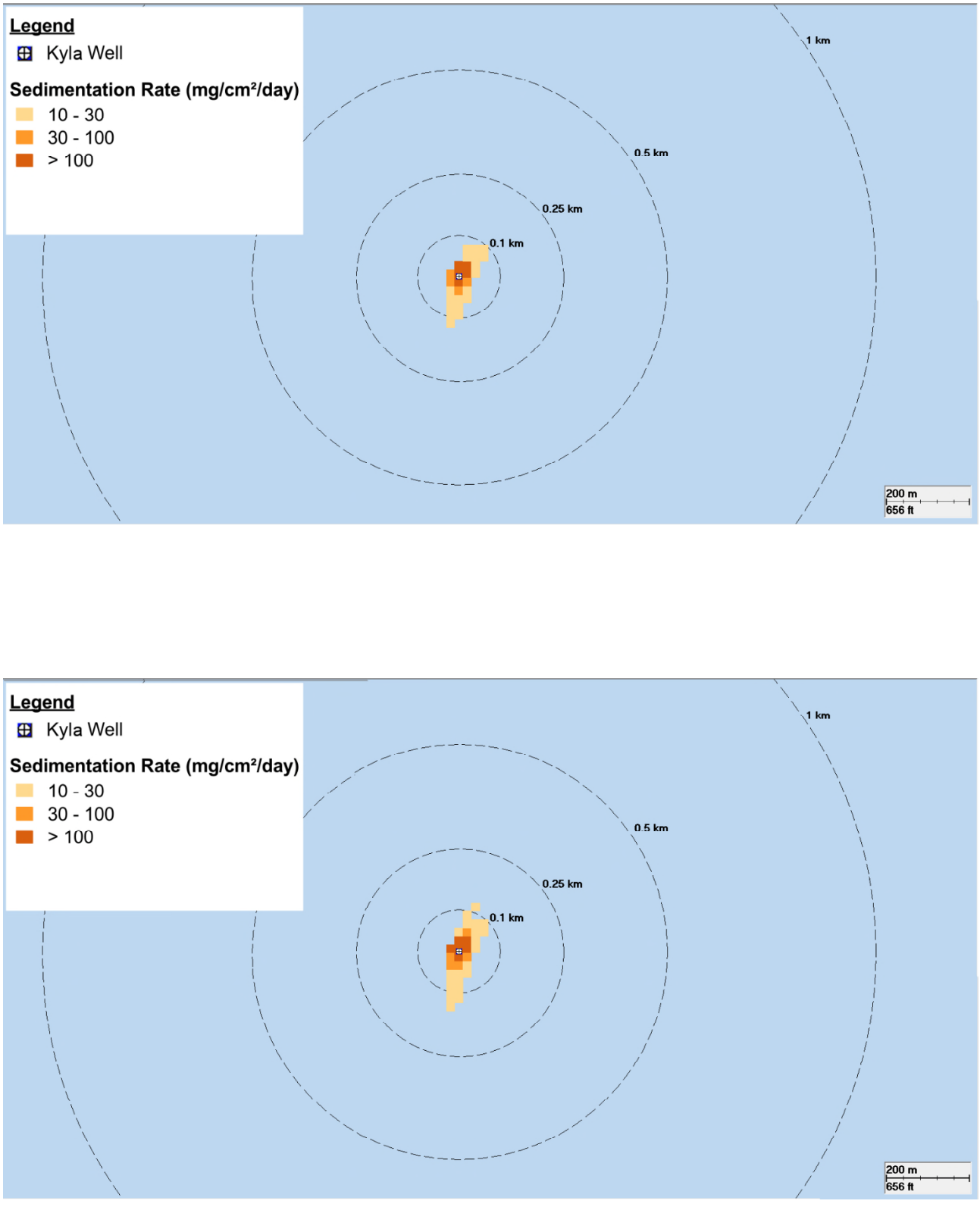


Figure 6.2 **Example plan-view screenshots of the predicted sedimentation rate (in each grid cell) 72 hours (top image) and 96 hours (bottom image) after the commencement of the near-seabed discharges of drilling cuttings and muds. Screenshot results are from 1 simulation of the 100 modelled as part of the study.**

6.1.2 Total Suspended Solids

Figure 6.3 and Figure 6.4 present model screenshots of the TSS concentrations during the modelled drilling and discharge operation during the near-seabed discharges from a single simulation. Additionally, Figure 6.5 and Figure 6.6 present the associated TSS concentration during the near-surface discharges also during a single simulation.

The model screenshots illustrate the dynamic nature of the TSS plume and provide both an aerial (plan) view illustrating the predicted TSS concentrations within the water column (cross section) along a given transect.

These images have been included to provide an example “snapshot” of the predicted orientation and size of the TSS plume influenced by the time-varying current directions and speeds.

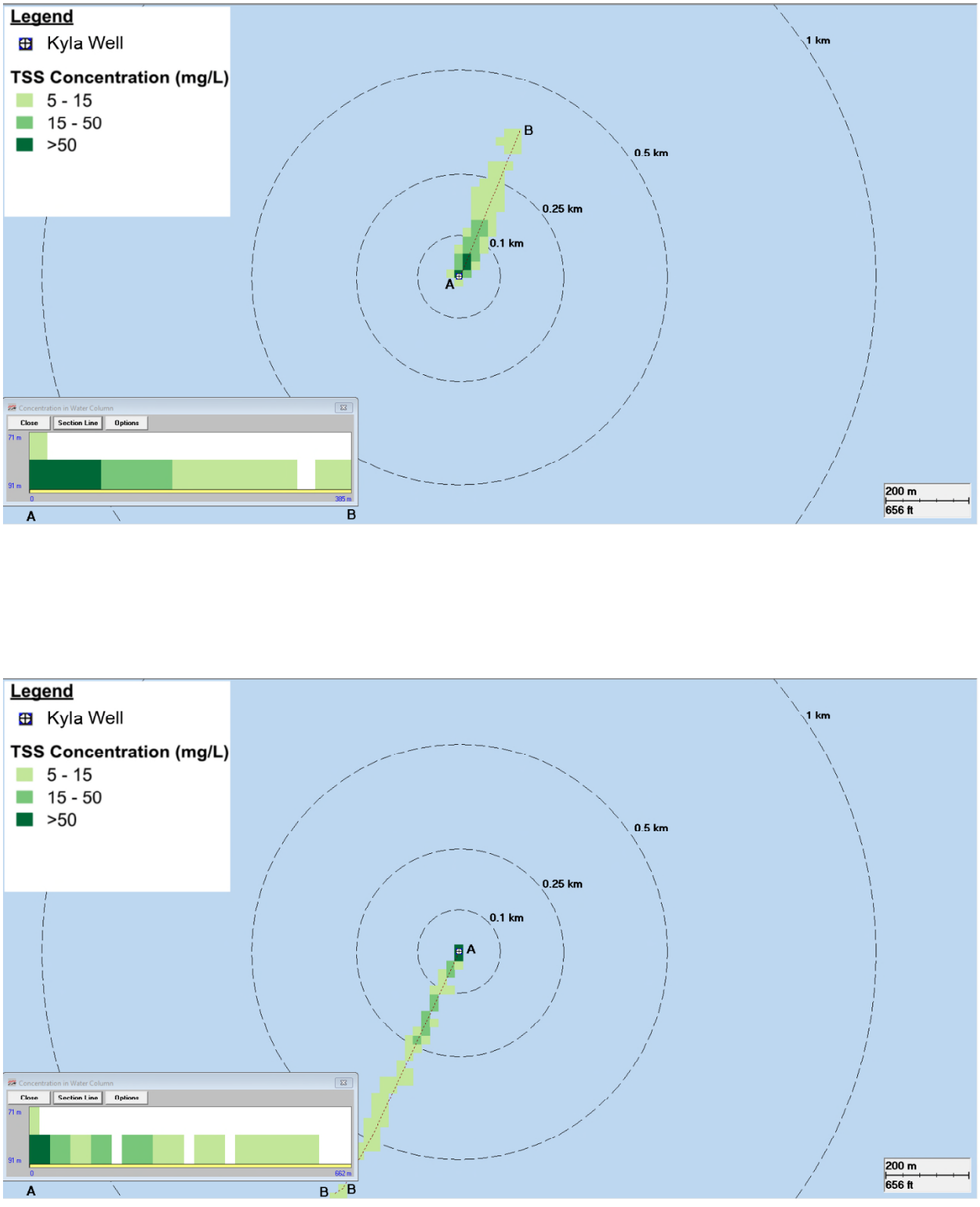


Figure 6.3 Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 3 hours (top image) and 6 hours (bottom image) after the commencement of the near-seabed discharges of drilling cuttings and muds. Screenshot results are from 1 simulation of the 100 modelled as part of the study.

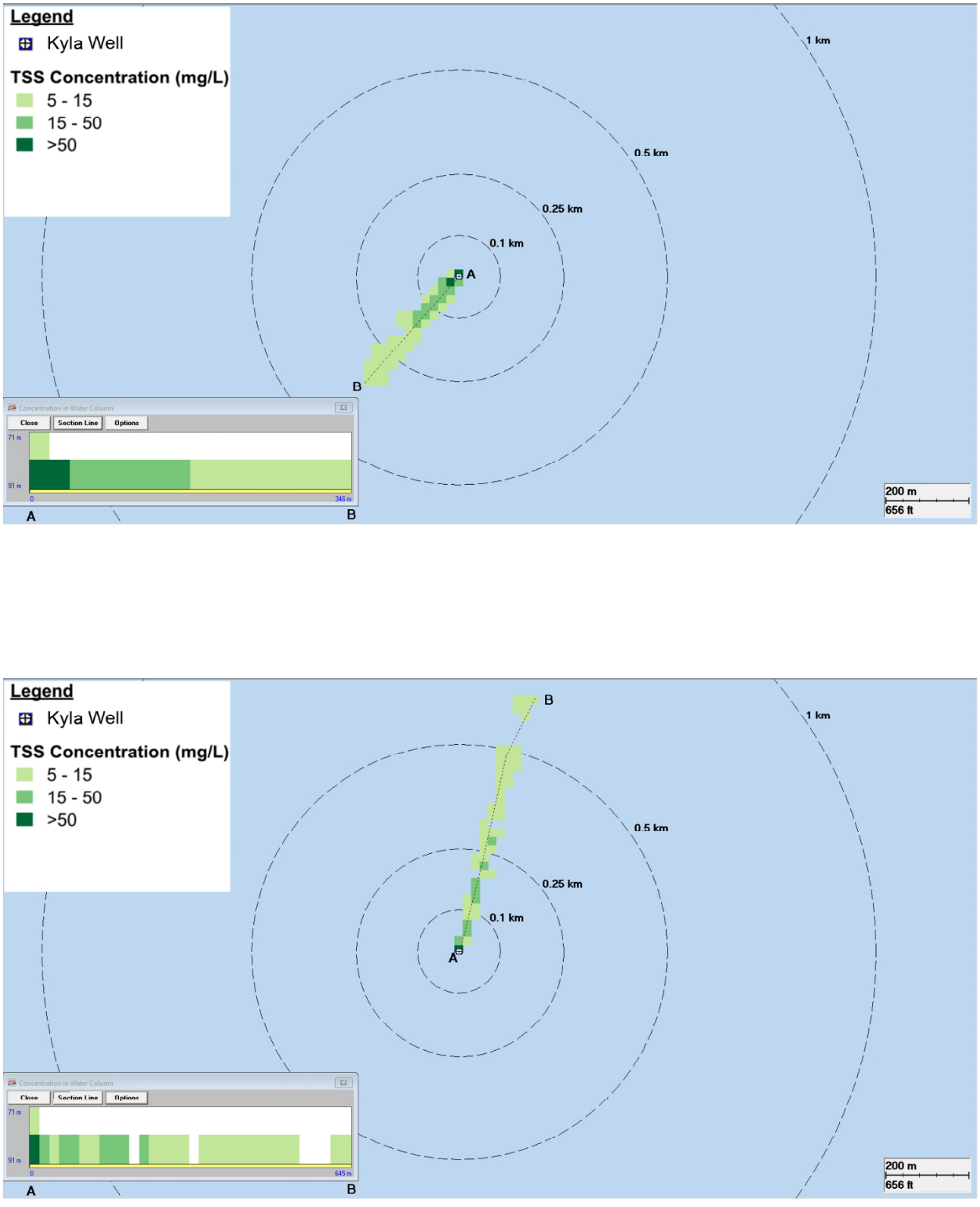


Figure 6.4 Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 9 hours (top image) and 12 hours (bottom image) after the commencement of the near-seabed discharges of drilling cuttings and muds. Screenshot results are from 1 simulation of the 100 modelled as part of the study.

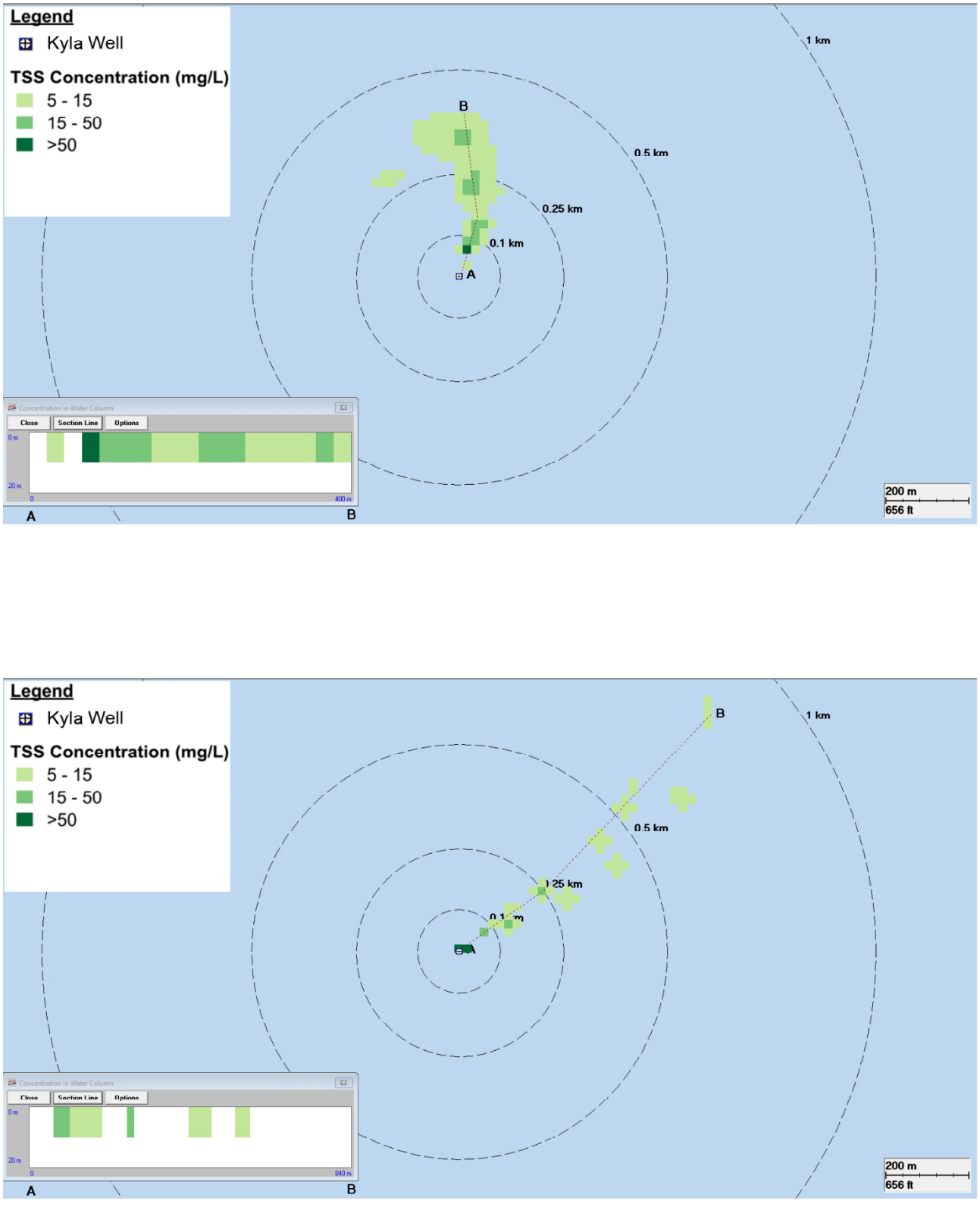


Figure 6.5 Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 3 hours (top image) and 6 hours (bottom image) after the commencement of the surface discharges of drilling cuttings and muds. Screenshot results are from 1 simulation of the 100 modelled as part of the study.

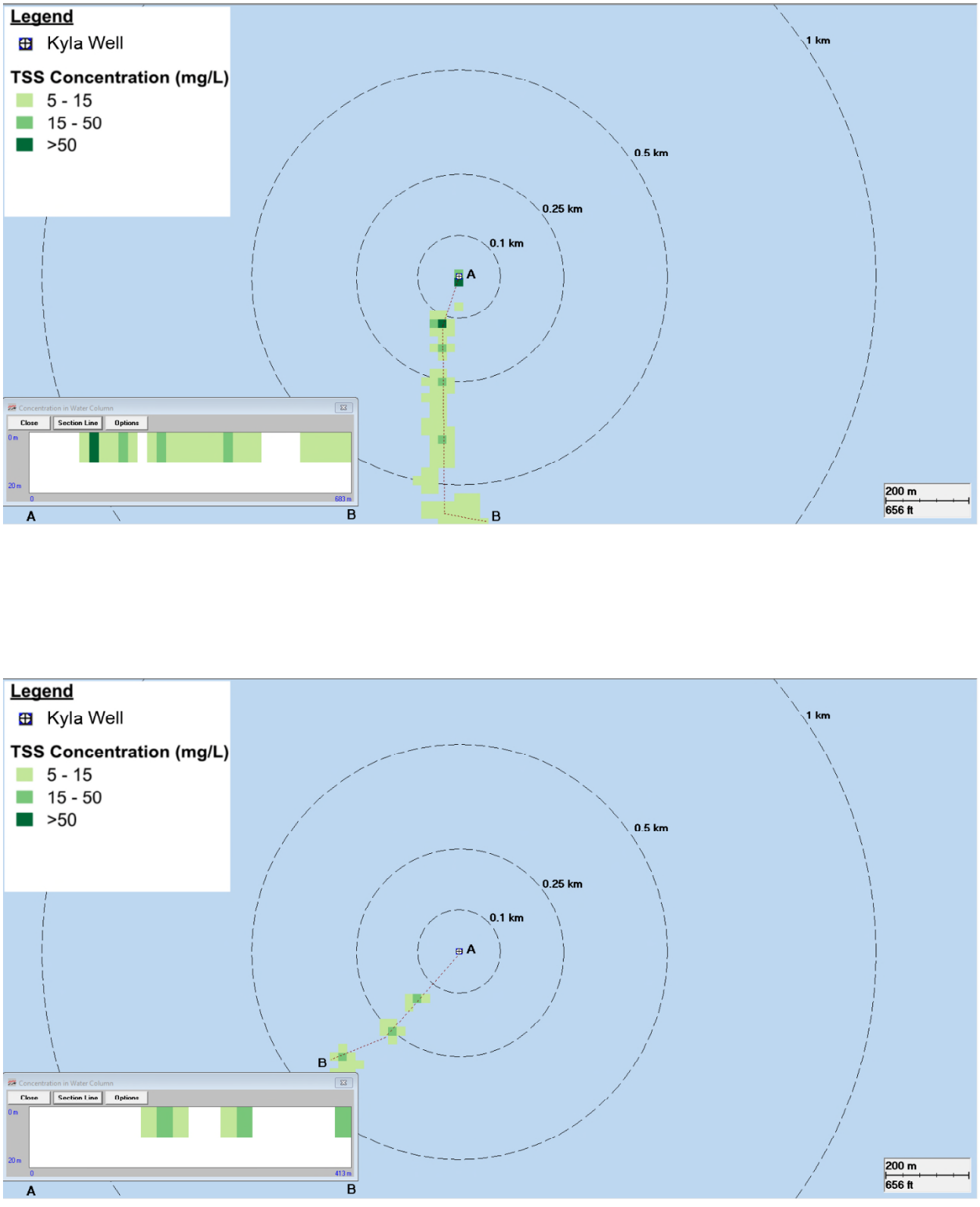


Figure 6.6 Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 9 hours (top image) and 12 hours (bottom image) after the commencement of the surface discharges of drilling cuttings and muds. Screenshot results are from 1 simulation of the 100 modelled as part of the study.

6.2 Stochastic Modelling Results

6.2.1 Deposition

Figure 6.7 presents the maximum sedimentation rates and equivalent total bottom thickness in each grid cell from all simulations (100 per release location) to define the potential exposure from the discharge of cuttings and muds for the proposed drilling program, to define the potential exposure from the discharge of cuttings and muds for the modelled discharge program.

The maximum predicted thickness of deposited cuttings and muds was predominantly associated with the drilling of the 36- and 26-inch bores, which were returned directly to seafloor from a discharge height of 2 m above the seafloor. A maximum thickness of 0.57 m was predicted within 50 m of the discharge location.

Table 6.1 summarise the total area of coverage and the maximum distances from the release location for each sedimentation rate (and equivalent total bottom thickness) of 10 mg/cm²/day (1.0 mm), 30 mg/cm²/day (3.0 mm) and 100 mg/cm²/day (10.2 mm; Table 6.1) for the modelled 26.4-day discharge program.

Based on the assessment of 100 simulations the maximum distances from the release location to the edge of the low exposure (10 mg/cm²/day [1.0 mm]) , moderate exposure (30 mg/cm²/day [3.0 mm]) and high exposure (100 mg/cm²/day [10.2 mm]) thresholds were 0.33 km, 0.15 km and 0.06 km, respectively.

The total area of coverage for the low exposure threshold, or greater, was 0.12 km^2 (Table 6.1).

Table 6.1 Predicted areas of coverage and maximum distances from the release location for each reporting threshold based on the results of all 100 simulations.

Annual assessment			
Sedimentation rate (mg/m^2/day)	**Equivalent total sediment bottom thickness* (mm)^**	**Total area of coverage (km^2)**	**Maximum distance (km) from the release location**
10	1.0	0.12	0.33
30	3.0	0.02	0.15
100	10.2	0.01	0.06

* Based on anticipated total discharge duration and assuming final settled in-situ bulk density of 2,600 kg/m^3

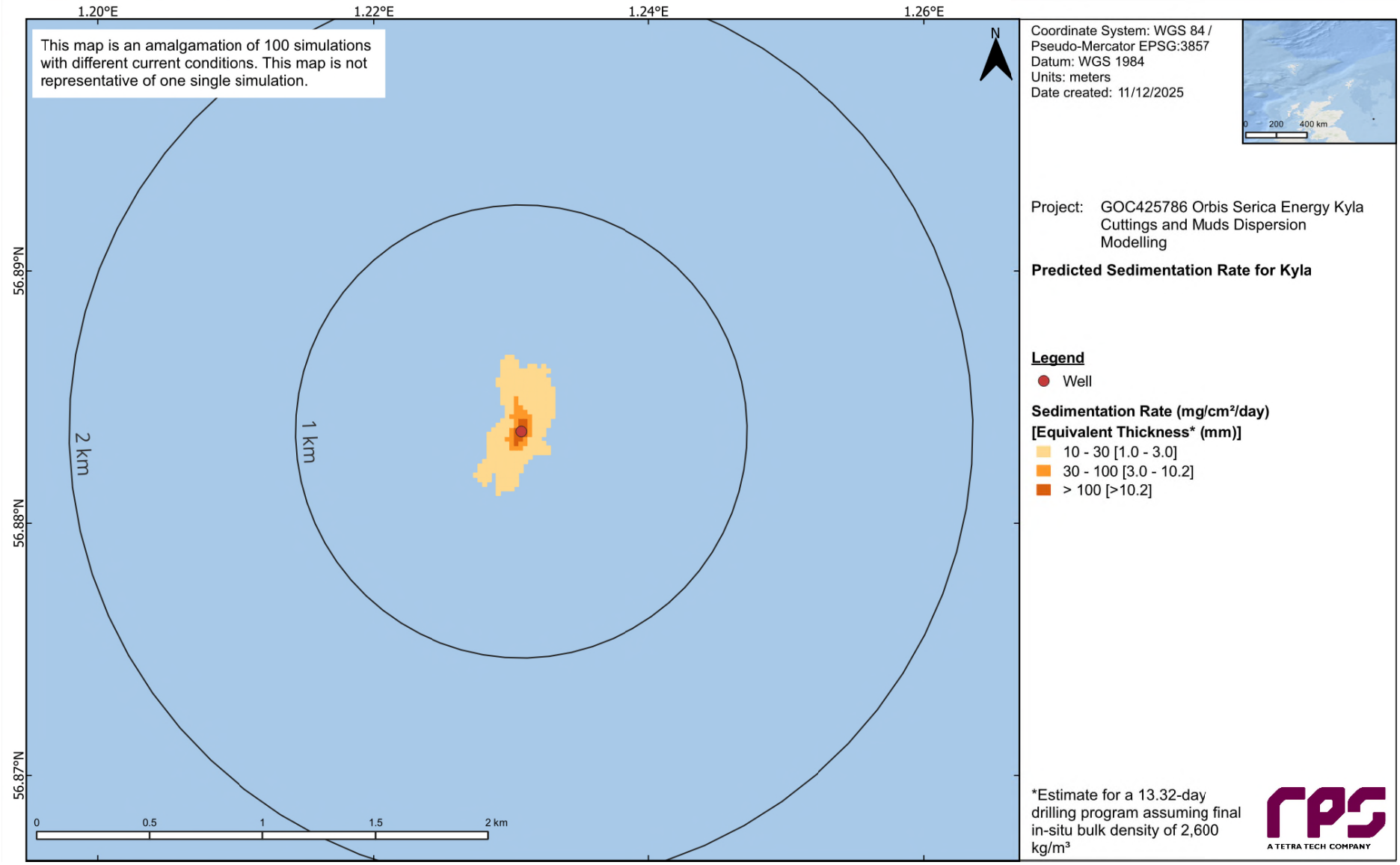


Figure 6.7 Predicted maximum sedimentation rate and equivalent thickness from the discharge of drill cuttings and muds. Results are based on 100 simulations and represent annual conditions.

6.2.2 Total Suspended Solids

Figure 6.8 and Figure 6.9 illustrate the maximum moving average concentrations computed over 1-hr and 24-hr in each grid cell from all 100 simulations, representing acute and chronic exposures respectively, to define the potential exposure from the discharge of cuttings and muds.

Table 6.2 summarises the total area of coverage and maximum distances from the release location for each TSS concentration threshold based on acute and chronic exposures.

Based on the assessment of 100 simulations, the maximum distance from the release location to the edge of the low exposure TSS concentration threshold (10 mg/L) for acute exposure (1-hr averaged concentration) was 1.02 km. Additionally, the maximum distance from the release location to the edge of the moderate exposure TSS concentration threshold (50 mg/L) for acute exposure (1-hr averaged concentration) was 0.27 km. High exposure (100 mg/L) TSS concentrations did not exceed 0.27 km from the release location. The total area of coverage for the low exposure threshold, or greater, was 1.19 km^2 (Table 6.2).

The maximum distance from the release location to the edge of the low exposure TSS concentration threshold (5 mg/L) for chronic exposure (24-hr averaged concentration) was 0.41 km. Additionally, the maximum distance from the release location to the edge of the chronic moderate exposure TSS concentration threshold (15 mg/L) was 0.19 km. Chronic high exposure (50 mg/L) TSS did not exceed 0.08 km from the release location. The total area of coverage for the low exposure threshold was 0.16 km^2 (Table 6.2).

The discharge of cuttings and muds will lead to relatively short-lived increased TSS concentrations of typically up to 24 hours, which are expected to dilute and reduce with distance from the release location to concentrations below the reporting thresholds. Based on the temporary elevated concentrations of TSS concentrations at the low exposure threshold, and the limited occurrence of the very localised high exposure, the impact likelihood is thus considered low.

Table 6.2 Predicted total areas of coverage and maximum distances to acute and chronic exposure from the release location to each reporting threshold based on the results of all 100 simulations.

	Annual	
Reporting threshold (mg/L)	**Total area of coverage (km^2)**	**Maximum distance (km) from the release location**
	Acute Exposure (1-hr averaged concentration)	
10	1.19	1.02
50	0.10	0.27
100	0.08	0.27
	Chronic Exposure (24-hr averaged concentration)	
5	0.16	0.41
15	0.05	0.19
50	0.01	0.08

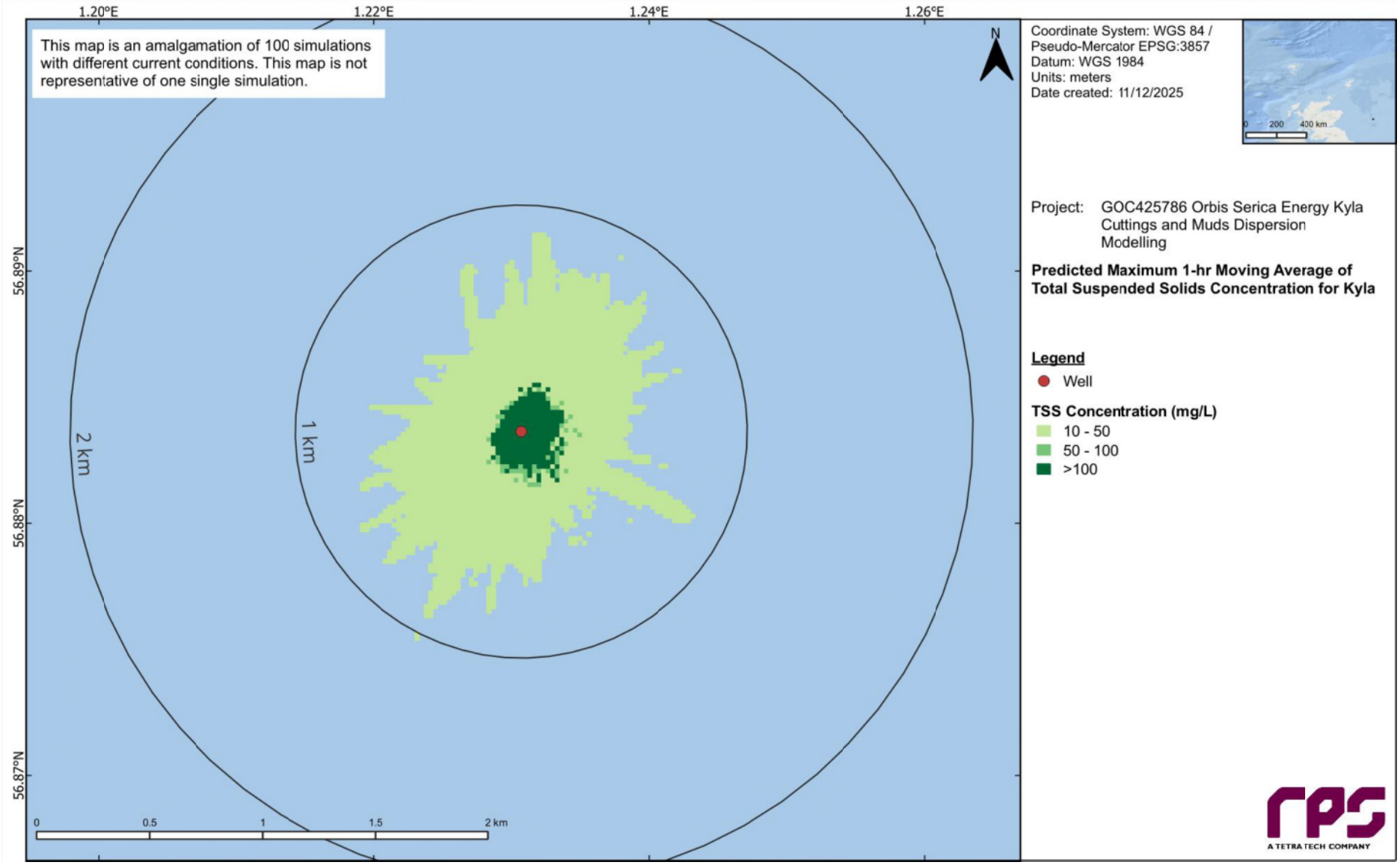


Figure 6.8 Predicted maximum 1-hr moving average of TSS concentrations, representing acute exposure, from the discharge of drill cuttings and muds. Results are based on 100 simulations and represent annual conditions.

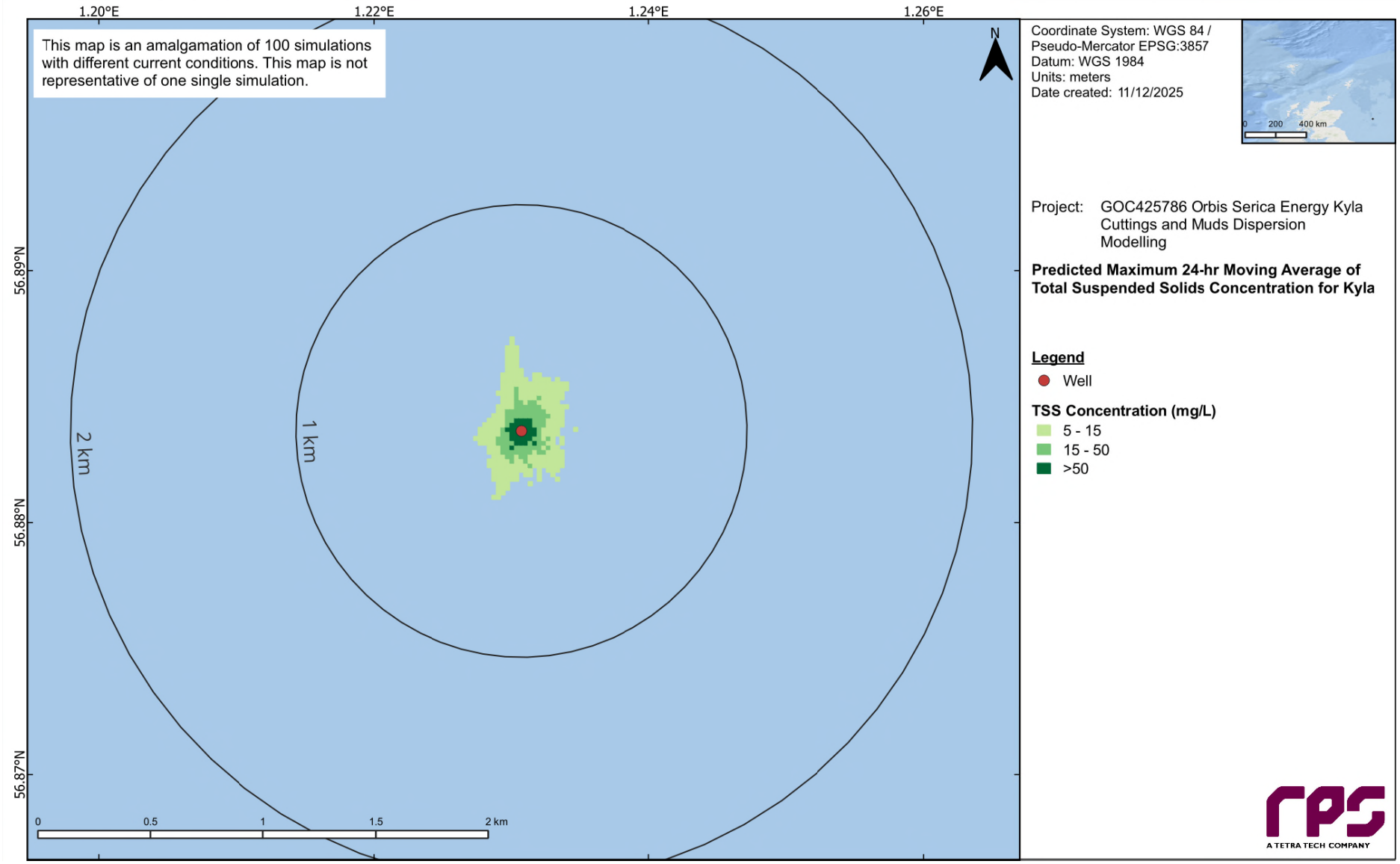


Figure 6.9 Predicted maximum 24-hr moving average of TSS concentrations, representing chronic exposure, from the discharge of drill cuttings and muds. Results are based on 100 simulations and represent annual conditions.

7 References

Akinbamini, OE, Anifowose, B & Obioma, EC 2022, 'Oil Spill Modeling for the Mariner Oil Field, East of Shetland, United Kingdom, North Sea', *Journal of Environmental Engineering*, vol. 148, no. 8, p.04022037.

Albert, PC & Prosser, CM 2023, 'Modeling demonstrates minimal ecological risks of cuttings discharges associated to oil and gas drilling with deep water wells', *Marine Pollution Bulletin*, vol. 186, pp. 114421.

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Babcock, R & Davies P 1991, 'Effects of sedimentation on settlement of *Acropova millepora*', *Coral Reef*, vol. 9, 205–208.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Browne, NK, Tay, J, Todd, PA 2015, 'Recreating pulsed turbidity events to determine coral–sediment thresholds for active management', *Journal of Experimental Marine Biology and Ecology*, vol. 466, pp.98–109.

Burns, K, Codi, S, Furnas, M, Heggie, D, Holdway, D, King, B, & McAllister, F 1999, 'Dispersion and Fate of Produced Formation Water Constituents in an Australian Northwest Shelf Shallow Water Ecosystem', *Marine Pollution Bulletin*, vol. 38, no. 7, pp. 593–603.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Dyer, KR 1986, 'Coastal and Estuarine Sediment Dynamics', John Wiley & Sons Ltd., Chichester.

Erftemeijer, PLA, Riegl, B, Hoeksema, BW & Todd, PA 2012, 'Environmental impacts of dredging and other sediment disturbances on corals: A review', *Marine Pollution Bulletin*, vol. 64, pp. 1717–1765.

Fabricius, KE 2005, 'Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis', *Marine Pollution Bulletin*, vol. 50, pp. 125– 46.

Gilmour JP 2002, 'Acute sedimentation causes size-specific mortality and asexual budding in the mushroom coral, *Fungia fungites*', *Marine and Freshwater Research*, vol. 53, no. 4, pp. 805–812.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Hodgson, G 1990, 'Sediment and the settlement of larvae of the reef coral *Pocillopora damicornis*', *Coral Reefs*, vol. 9, no.1, p.41-43.

Huthnance, JM 1991, 'Physical oceanography of the North Sea', *Ocean and Shoreline Management*, vol. 16, no. 3-4, pp. 199-231.

International Association of Oil & Gas Producers (IOGP) 2016, 'Environmental fates and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations', Technical Report 543, IOGP, London, United Kingdom.

Isaji, T & Spaulding, M 1984, ‘A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank’, *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, ‘Stepwise-continuous-variable-rectangular grid hydrodynamics model’, Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

King, B & McAllister, FA 1997, Modelling the Dispersion of Produced Water Discharge in Australia 1 & 2. Australian Institute of Marine Science, Townsville.

King, B & McAllister, FA 1998, ‘Modelling the dispersion of produced water discharges’, *APPEA Journal*, pp.681–691.

King, B, Brushett, B & Lemckert, C 2010, 'A case study of consensus modelling for tracking oil spills', *Proceedings of IOP Conference Series: Earth and Environmental Science*, vol. 11, no. 1, p. 012025, IOP Publishing.

Koh, HL & Teh, SY 2011, 'Simulation of drill cuttings dispersion and deposition in South China Sea', Proceedings of the International MultiConference of Engineers and Computer Scientists, vol. 2.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, ‘Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data’, *Oceanology*, vol. 43, no. 5, pp. 632–642.

Lee, AJ 1980, 'Chapter 14 North Sea: Physical Oceanography', Elsevier Oceanography Series, vol. 24, no. Part B, pp. 467–493.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, ‘Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data’, *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Makarynskyy, O, Langtry, S, Zapata, M & Rayson, M 2010, 'Validations of Hydrodynamic, Wave, and Dredging Simulations in Nearshore Environments', in Estuarine and Coastal Modeling, pp. 547-565, ASCE Library, Reston, USA.

Makarynskyy, O, Makarynska, D, Rayson, M & Langtry, S 2015, 'Combining deterministic modelling with artificial neural networks for suspended sediment estimates', *Applied Soft Computing*, vol. 35, pp. 247-256.

Mathis, M, Elizalde, A, Mikolajewicz, U & Pohlmann, T 2015, 'Variability patterns of the general circulation and sea water temperature in the North Sea', *Progress in Oceanography*, vol. 135, pp 91–112.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, ‘Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan’, *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

Melsom, A 2005, ‘Mesoscale activity in the North Sea as seen in ensemble simulations’, *Ocean Dynamics*, vol. 55, no. 3–4, pp. 338–350.

MScience 2011, ‘Browse LNG development: Sediment impact threshold developed for James Price Point nearshore benthic communities’, Report: MSA157R11 to Woodside Energy Limited, MScience, Nedlands, Western Australia.

Neff, J 2005, ‘Composition, environment fates, and biological effect of water based drilling fluids and cuttings discharged to the marine environment: A synthesis and annotated bibliography’, Battelle, Duxbury.

Owen, A 1980, ‘A three-dimensional model of the Bristol Channel’, *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

OSPAR Commission (OSPAR) 2000, Quality status report 2000 Region II - Greater North Sea. OSPAR Commission, London. 136 pp.

Qiu, B & Chen, S 2010, ‘Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system’, *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Spaulding, ML 1994, ‘Drilling, production fluids dispersion predicted by model’, *Offshore*, vol. 54, no. 4, pp. 78–82.

Stump, R, Kettle, B, Campbell, D, Zarillo, G & Shay N 2019, 'White Paper on Biological Thresholds for Adaptive Dredge Management', Report to United States Army Corps of Engineers, South Atlantic Division, Jacksonville District.

Talouli, A, Gilbert, T & Monfils Gilbert, R 2009, 'Strategic Environmental Assessment and potential future shoreline impacts of the oil spill from WWII shipwreck Hoyo Maru Chuuk Lagoon-Federated States of Micronesia', Pacific Regional Environment Programme, Apia, Samoa.

TWMA, 2024a, 'Discover Rotomill', viewed 18 April 2024, https://twma.com/solutions/rotomill-2023#overview.

TWMA 2024b, 'PSD Overview March 2024.pdf' (client provided document).

Winther, NG & Evensen, G 2006, 'A hybrid coordinate ocean model for shelf sea simulation', *Ocean Modelling*, vol. 13, no. 3–4, pp. 221–237.

Winther, NG & Johannessen, JA 2006, 'North Sea circulation: Atlantic inflow and its destination', *Journal of Geophysical Research: Oceans*, vol. 111, no.C12.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji,T, King, B, & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

Zigic, S, Makarynskyy, O, Langtry, S & Westbrook, G 2009, 'A numerical modelling study for the proposed increase in Barramundi production, Cone Bay, Western Australia', in Estuarine and Coastal Modeling, pp. 428-446, ASCE Library, Reston, USA.

APPENDIX D:
Underwater Noise Modelling

Subsea Piling in the Kyle Oil Field (UKCS Block 29/2c): Underwater Noise Modelling Assessment

[redacted]

31st October 2025

Subacoustech Environmental Report No.
P435R0101

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This report is a controlled document. The report documentation page lists the version number, record of changes, referencing information, abstract and other documentation details.

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Executive Summary

An assessment of the likely effect of underwater noise on marine mammals and fish from planned offshore piling at the Kyle Oil Field (UKCS Block 29/2c) in the North Sea has been undertaken by Subacoustech Environmental Ltd. The assessment covers the noise generated from impact piling of a valve skid structure. Detailed numerical modelling of the works was used to generate noise contours, which were then used to predict the likely ranges to the relevant noise exposure criteria for marine mammals and fish.

The results have been interpreted using the guidelines provided in Southall *et al.* (2019) for marine mammals and Popper *et al.* (2014) for fish. These interpretations are based on worst-case parameters with no implemented mitigation measures.

It is predicted that marine mammals such as harbour porpoise would need to be 20 m from the impact piling operation during piling at maximum energy to exceed the permanent auditory injury criteria, with smaller ranges for other species of marine mammal. For fish, it is unlikely that noise from impact piling will cause injury at ranges greater than 10 m when considering a fleeing receptor. However, fish with swim bladders involved in their hearing (e.g., cod, sprat and shad) are at risk of mortality if they remain within 180 m of the piling for the full 8-hour installation period.

Note that the modelling calculations and predicted impact ranges will produce results that should be considered indicative of the onset of effects on receptors during the works and should not be considered as absolute ranges.

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Terminology

Cumulative Sound Exposure Level (SEL_{cum} or $L_{E,p,t}$)	Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source.
Decibel (dB)	A customary scale commonly used (in various ways) for reporting levels of sound. The dB represents a ratio/comparison of a sound measurement (e.g., sound pressure) over a fixed reference level. The dB symbol is followed by a reference value (e.g., re 1 µPa).
Level of the Peak Sound Pressure (SPL_{peak} or $L_{p,pk}$)	The highest (zero-peak) positive or negative sound pressure, in decibels.
Peak pressure	The highest pressure above or below ambient that is associated with a sound wave.
Peak-to-peak pressure	The sum of the highest positive and negative pressures that are associated with a sound wave.
Permanent Threshold Shift (PTS)	Noise threshold that represents the onset level of a permanent impairment hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity.
Root Mean Square (RMS)	The square root of the arithmetic average of a set of squared instantaneous values. Used for presentation of an average sound pressure level.
Sound Exposure Level (SEL or $L_{E,p,t}$)	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level, and is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Single Pulse Sound Exposure Level, (SEL_{sp} or $L_{E,p,sp}$)	Calculation of the sound exposure level representative of a single noise impulse, typically a pile strike.
Sound Pressure Level (SPL or L_p)	The sound pressure level is an expression of sound pressure using the decibel (dB) scale; the standard frequency pressures of which are 1 µPa for water and 20 µPa for air.
Temporary Threshold Shift (TTS)	Onset threshold level for a temporary reduction of hearing acuity caused by exposure to sound over time.
Unweighted sound level	Sound levels which are “raw” or have not been adjusted in any way, for example to account for the hearing ability of a species.
Weighted sound level	A sound level which has been adjusted with respect to a “auditory weighting function” or “weighting envelope” in the frequency domain, typically to make an unweighted level relevant to a particular species.

Units

dB	Decibel (sound pressure)
Hz	Hertz (frequency)
kg	Kilogram (mass)
kgm^{-3}	Kilogram per metre squared (density)
kJ	Kilojoule (energy)
kHz	Kilohertz (frequency)
km	Kilometre (distance)
km^2	Square kilometres (area)
m	Metre (distance)
mms^{-1}	Millimetres per second (particle velocity)
ms^{-1}	Metres per second (speed)
Pa	Pascal (pressure)
Pa^2s	Pascal squared seconds (acoustic energy)
µPa	Micropascal (pressure)

Acronyms

BGS	British Geological Survey
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
GIS	Geographic Information System
HF	High-Frequency Cetaceans
LF	Low-Frequency Cetaceans
NMPi	National Marine Plan Interactive
NPL	National Physical Laboratory
PCW	Phocid Carnivores in Water
PPV	Peak Particle Velocity
PTS	Permanent Threshold Shift
RMS	Root Mean Square
SE	Sound Exposure
SEL ($L_{E,p}$)	Sound Exposure Level
SEL_{cum} ($L_{E,p,t}$)	Cumulative Sound Exposure Level
SEL_{ss} ($L_{E,p,ss}$)	Single Strike Sound Exposure Level
SPL (L_p)	Sound Pressure Level
SPL_{peak} ($L_{p,pk}$)	Peak Sound Pressure Level
$SPL_{peak\text{-}to\text{-}peak}$ ($L_{p,pk\text{-}pk}$)	Peak-to-peak Sound Pressure Level
SPL_{RMS} ($L_{p,RMS}$)	Root Mean Square Sound Pressure Level
TTS	Temporary Threshold Shift
VHF	Very High-Frequency Cetaceans

1 Introduction

1.1 Project Overview

On behalf of Serica Energy Chinook Ltd (Serica), Orbis Energy Ltd have requested underwater noise modelling covering the noise related to offshore piling works at the Kyle Oil Field, located in UKCS Block 29/2c in the central North Sea.

Kyle is a ceased-production oil field located approximately 182 km to the southeast of Peterhead on the Scottish coastline. As part of the re-development project, Serica plan to install a piled valve skid structure at the proposed Kyle drill centre. A total of two valve skid structures are proposed to be installed, each with four piles per structure, installed via subsea impact piling. The potential noise and impacts on relevant marine fauna in the region from these works has been assessed using underwater noise modelling.

This report provides the results and findings of the detailed modelling assessment of the impact piling activities. The modelling has been used to predict the sound generated during these activities, and to assess the impact of these levels on sensitive marine species in the region, with particular focus on marine mammals and fish.

1.2 Study Area

The location of one of the skid structures, where the piling will take place, is marked in Figure 1-1, which has been used for this modelling. The modelling extent covers a 100 km × 100 km area around this location. Within the modelling extent, the bathymetry shows similar water depths throughout, with several strips of very deep water found to the west and southwest, reaching depths of up to 174 m.

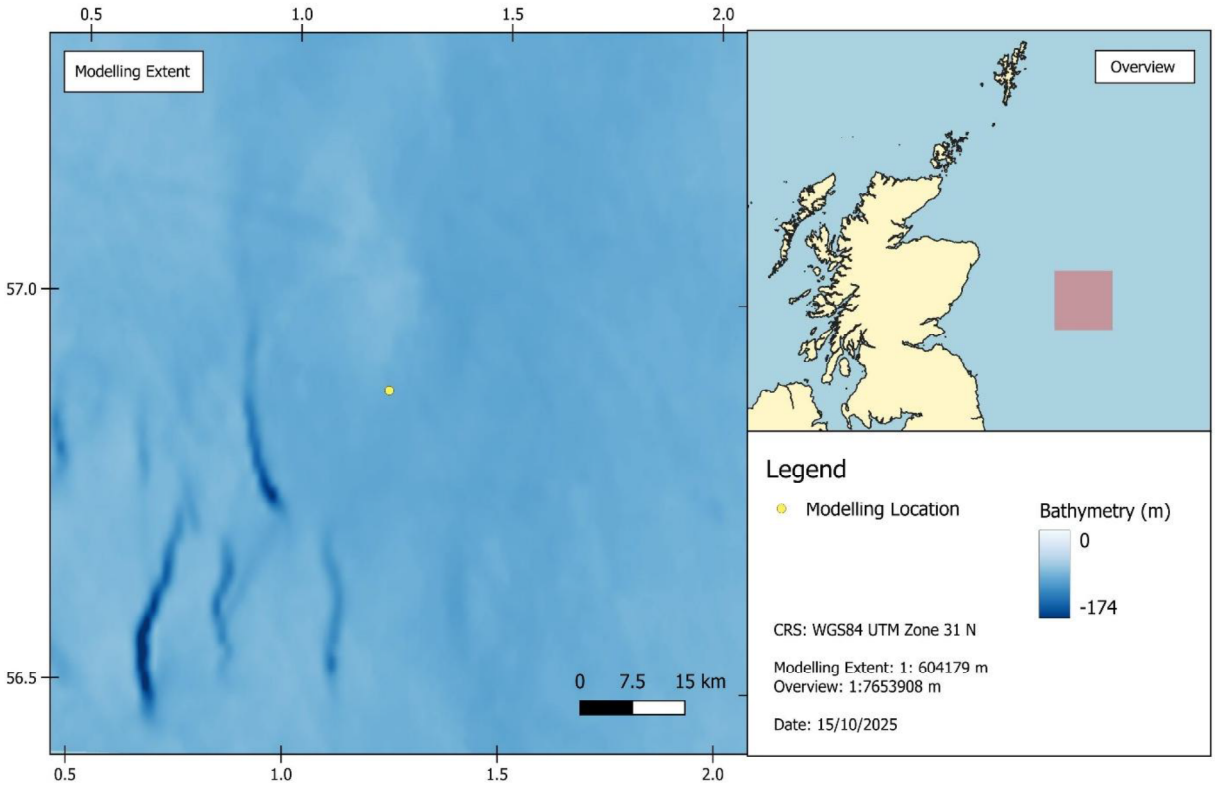


Figure 1-1: Overview of the modelling extent, including the location of the works which generates the noise source (modelling location) in the North Sea.

1.3 Noise Sources

A total of eight subsea piles are proposed to be installed across two skid structures (four subsea piles per structure). Each pile is estimated to take two hours to install, with a total of eight hours piling per day across a two-day period. A soft start is also included. The following details have been provided:

- Pile size: 0.61 m (24-inch) diameter x 24 m length, installed to a depth of 20 m.
- Maximum hammer blow energy: 90 kJ.
- Maximum blow rate: 50 blows per minute.
- Soft start with a ramp up from 30% energy to full energy over 5 minutes, with a reduced blow rate of 6 strikes per minute.

Impact piling has been identified as the only noise generating activity associated with the works. Details of the input parameters used for modelling this noise source in this assessment are presented in Section 3.1.5.

1.4 Document Overview

This report presents a detailed assessment of the potential underwater noise from the impact piling activities in the central North Sea, and covers the following:

- Section 2: Review of background information on measuring and assessing underwater noise.
- Section 3: Discussion of the modelling approach, input parameters and assumptions for the noise modelling undertaken.
- Section 4: Presentation of detailed subsea noise modelling and interpretation of the results using suitable noise metrics and criteria.
- Section 5: Summary and conclusions.

2 Underwater Noise Concepts

Sound travels much faster in water (approximately 1,500 ms^{-1}) than in air (343 ms^{-1}) as water is relatively incompressible and has a higher density than air. This affects the way in which sound measurements are expressed between the two mediums, which means that underwater sound levels are not directly comparable to airborne sound levels. This is noted for context; this report does not contain or include any reference to airborne sound levels.

2.1 Units of Measurement

Sound measurements are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound. The dB scale represents a ratio, and therefore, it is used with a reference unit, which is the base from which the ratio is expressed. The fundamental definition of the dB scale is given in Equation 1:

(1)

$$Sound\ pressure\ level\ (L_p) = 20 \log_{10}\left(\frac{P}{P_{ref}}\right)$$

where P is pressure, measured in Pascals (Pa), and P_{ref} is the reference pressure, given as 1 µPa (1x10^{-6} Pa) as defined in ISO 18405:2017 for underwater noise. Noise can be quantified using various metrics depending on the nature of the sound, as discussed below.

2.1.1 Sound Pressure Level

Sound Pressure Level (SPL or L_p) is a measure of the pressure variation caused by sound waves, expressed in decibels (dB), as seen in Equation 1. Variations of L_p are used depending on the noise source being measured. Unless otherwise defined, all L_p noise levels in this report are referenced to 1 µPa.

2.1.1.1 Level of the Mean Squared Sound Pressure

For continuous, non-impulsive noise sources such as drilling or vibropiling, an unweighted sound pressure level, averaged over a measurement period, known as a root mean squared (RMS) sound pressure level (SPL_{RMS} or $L_{p,RMS}$), can be used to represent the noise levels. The RMS period must be specified (e.g. $L_{p,RMS(125ms)}$), as the mean level can vary significantly depending on the measurement duration.

2.1.1.2 Level of the Peak Sound Pressure

Transient, impulsive pressure waves, such as generated from impact piling, are usually expressed using level of the peak sound pressure (SPL_{peak} or $L_{p,pk}$). This is calculated using the maximum pressure variation from positive to zero, representing the peak change in pressure as the transient wave propagates. A further variation of this is the peak-to-peak sound pressure level ($SPL_{peak\text{-}peak}$ or $L_{p,pk\text{-}pk}$) which considers the maximum pressure variation from positive to negative. For a symmetrically distributed wave, the peak-to-peak pressure is twice the peak level, or 6 dB higher.

2.1.2 Sound Exposure Level

Sound Exposure Level (SEL or $L_{E,p}$) is a measures Sound Exposure (SE), which represent the total acoustic energy of a sound event in dB, accounting for both the sound's intensity and duration. $L_{E,p}$ provides a way to quantify the total energy in a sound, making it useful for assessing the impact of both continuous and transient sounds. Variations of $L_{E,p}$ are used depending on the noise source being measured. For context, $L_{E,p}$ can be compared $L_{p,\mathrm{RMS}}$ using Equation 2:

(2)

$$L_{E,p} = L_{p,RMS} + 10 \times \log_{10} T$$

where the $L_{p,RMS}$ is a measure of the average level of broadband noise and the $L_{E,p}$ sums the cumulative broadband noise energy. For continuous sounds shorter than one second, the $L_{E,p}$ is lower than the $L_{p,RMS}$. For durations longer than one second, the $L_{E,p}$ exceeds the $L_{p,RMS}$ (e.g., a 10-second sound results in a 10 dB higher SEL and a 100-second sound gives a 20 dB higher SEL). Unless otherwise defined, all $L_{E,p}$ noise levels in this report are referenced to 1 µPa^{2}s.

2.1.2.1 Single Strike Sound Exposure Level

Single strike Sound Exposure Level ($\mathrm{SEL_{ss}}$ or $L_{E,p,ss}$) refers to the total acoustic energy from a single, loud, short duration noise event (such as a blast or impact) measured over a specified duration. This can be expressed using Equation 3:

(3)

$$L_{E,p,ss} = 10 \times \log_{10} \left(\frac{\int_0^T p^2(t)dt}{{p^2}_{ref} T_{ref}} \right)$$

where p is the acoustic pressure in Pascals, T is the total duration of sound in seconds, and t is time in seconds.

2.1.2.2 Cumulative Sound Exposure Level

A cumulative Sound Exposure Level ($\mathrm{SEL_{cum}}$ or $L_{E,p,t}$) accounts for the exposure from multiple impulses or pile strikes over time, where the number of impulses replaces the T in the Equation 3, leading to Equation 4:

(4)

$$L_{E,cum} = L_{E,p,ss} + 10 \times \log_{10} X$$

Where X is the total number of impulses or strikes within a specific timeframe.

2.2 Properties of Sound

2.2.1 Impulsive vs Non-impulsive

Sound can be categorised loosely into two types: impulsive and non-impulsive. These can be defined as:

- Non-impulsive: a steady-state sound. It does not necessarily have to have a long duration.
    - Examples: vibropiling, drilling
- Impulsive: a sound with a high peak sound pressure, short duration, fast rise-time and broad frequency content at the source.
    - Examples: impact piling, seismic airguns, explosives

These differences are crucial for assessing auditory injury, as impulsive sound is typically more harmful than non-impulsive sound. Different metrics are needed to describe these distinct sound sources:

- Impulsive: Use $L_{p,\mathrm{pk}}$, $L_{E,p,\mathrm{ss}}$ or $L_{E,p,t}$
- Non-impulsive: Use $L_{p,\mathrm{RMS}}$ or $L_{E,p,t}$

Categorising sound as impulsive or non-impulsive can be challenging, especially over long distances. As impulsive sounds travel, their energy dissipates, making them less impulsive and therefore potentially less injurious. Ongoing research, such as Martin *et al.* (2020), aims to define these categories. Hastie *et al.* (2019) found that impulsive sound can be considered non-impulsive 3.5 km from the source, while Southall (2021) suggests noise should be non-impulsive if energy above 10 kHz is absent. Research is ongoing to refine pulse characteristics, like kurtosis, for better categorisation.

2.2.2 Particle Motion

Particle motion, a key component of sound, describes the back-and-forth movement of particles in a medium (such as water) caused by sound waves. Unlike sound pressure, particle motion contains directional information (Hawkins and Popper, 2017). It is typically quantified by peak particle velocity (PPV), though acceleration or displacement can also be used. Research shows many fish species and marine invertebrates are sensitive to particle motion (e.g., Popper and Hawkins, 2019; Nedelec *et al.,* 2016, Radford *et al.,* 2012, Sole *et al.,* 2023), but sound pressure metrics are still more commonly used due to limited data (Popper and Hawkins, 2018). Calls for further research on particle motion levels and effects continue.

2.3 Analysis of Environmental Effects: Assessment Criteria

Over the past 20 years, it has become clear that human-generated underwater noise impacts marine species. The severity of these effects depends on factors like sound level, frequency, exposure duration, and repetition rate (Hastings and Popper, 2005). As a result, research on aquatic species' hearing abilities has grown, with studies focused on high-level noise sources such as seismic airguns, impact piling, and blasting, which have the most immediate environmental effects, though interest in chronic noise exposure is rising.

The impacts of underwater sound on marine species can be broadly summarised as follows:

- Physical traumatic injury and fatality.
- Auditory injury (either permanent or temporary).
- Behavioural responses

The following sections outline the underwater noise criteria used in this study for marine mammals and fish in the North Sea.

2.3.1 Marine Mammals

2.3.1.1 Southall *et al.* (2019): Auditory Injury (PTS and TTS) criteria

Southall *et al.* (2019) is one of the most recognised references for marine mammal hearing thresholds and aligns with the thresholds provided in the National Marine Fisheries Service (NMFS, 2018) guidance. At the time of undertaking the assessment, although NMFS (2024) had been published as an updated weighting criteria and impact threshold, no UK regulators had provided guidance that the updated thresholds were acceptable and should be used in modelling assessments. Therefore, we continued with Southall *et al.* (2019) as the most trusted criteria at the time.

The Southall *et al.* (2019) guidance categorises marine mammals into groups based on similar species and applies filters to the unweighted noise levels to approximate their hearing sensitivities. These groups are summarised in Table 2-1, with auditory weighting functions in Figure 2-1. Additional groups for sirenians and other marine carnivores are provided but not included in this study, as these species are not common in the North Sea. It should be noted that the inclusion of "wtd" in $L_{E,p,t,\mathrm{wtd}}$ notation refers to a $L_{E,p,t}$ with an appropriate Southall *et al.* (2019) marine mammal weighting function applied.

Table 2-1: Marine mammal hearing groups (from Southall et al., 2019).

Hearing group	Auditory Weighting Function	Generalised hearing range	Species group	Example species
Low-frequency Cetaceans	LF	7 Hz to 35 kHz	Baleen whales	Sei Whale, Fin Whale, Minke Whale, Humpback Whale
High-frequency Cetaceans	HF	150 Hz to 160 kHz	Toothed whales, including dolphins and beaked whales	Bottlenose Dolphin, White-beaked Dolphin, Risso's Dolphin, Common Dolphin, Orca, Sperm Whale, Pilot Whale, Northern Bottlenose Whale
Very high-frequency Cetaceans	VHF	275 Hz to 160 kHz	True porpoise	Harbour porpoise
Phocid carnivores in water	PCW	50 Hz to 86 kHz	True seals	Harbour seal, Grey Seal

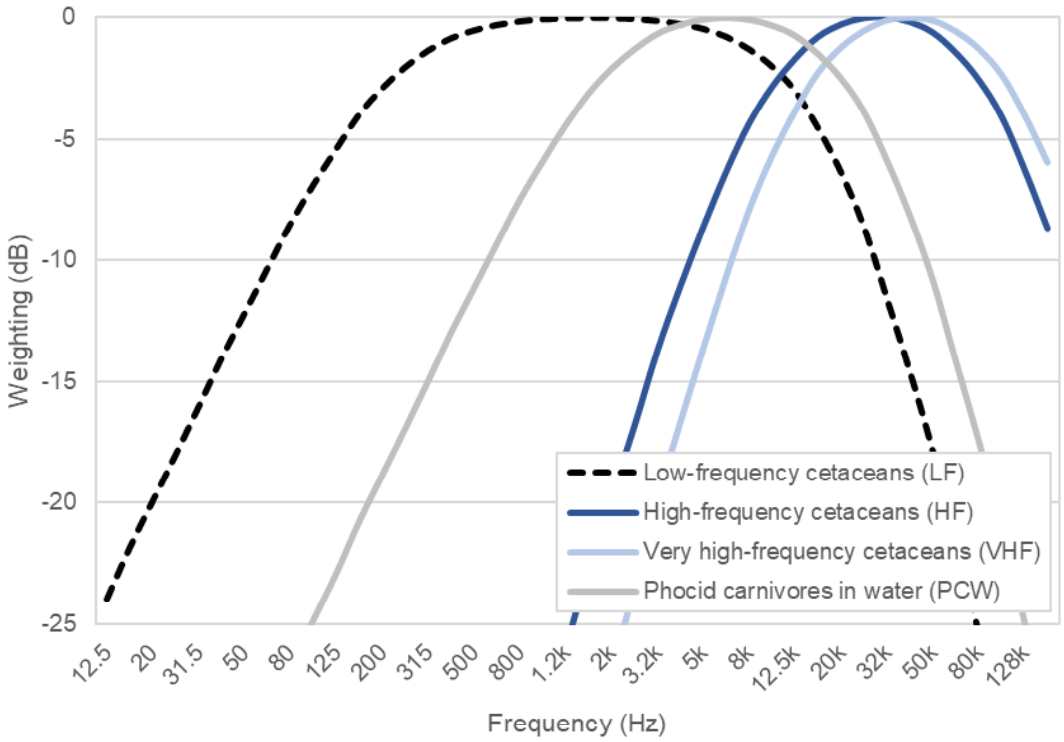


Figure 2-1: Auditory weighting functions for low-frequency cetaceans (LF), high-frequency cetaceans (HF), very high-frequency cetaceans (VHF), and phocid carnivores in water (PCW) (from Southall et al., 2019)

Southall *et al.* (2019) presents noise impact thresholds for marine mammal groups based on:

- The sound type (impulsive vs non-impulsive)
- The type of auditory injury of concern

Impact ranges based on impulsive criteria are recommended for most sources, except clearly non-impulsive ones. However, if the predicted range exceeds 3.5 km (see Section 2.2.1), the true impact range is likely to lie between the impulsive and non-impulsive ranges. Thus, both criteria are considered unless the sound source is explicitly non-impulsive.

For $L_{E,p,t}$ thresholds in marine mammals, a fleeing animal model is used, assuming the animal swims away from the sound source. These are worst-case assumptions, as marine mammals can swim faster under stress (Kastelein *et al.*, 2018), particularly at the start of a noisy event when they are closest to the source. The following flee speeds are applied for each marine mammal group:

- 2.1 ms^{-1} for LF cetaceans (Scottish Natural Heritage; SNH, 2016)
- 1.52 ms^{-1} for HF cetaceans (Bailey and Thompson, 2006)
- 1.4 ms^{-1} for VHF cetaceans (SNH, 2016)
- 1.8 ms^{-1} for PCW pinnipeds (SNH, 2016)

Southall *et al.* (2019) presents specific impact thresholds for impulsive and non-impulsive sound criteria, based on different of auditory injury associated with the characteristics of these sounds. Auditory injury is categorised into two types:

- PTS (permanent threshold shift): the greatest severity, which is unrecoverable (but incremental) reduction in hearing sensitivity.
- TTS (temporary threshold shift): the least severity, which is a short-term reduction in hearing sensitivity.

TTS represents the potential auditory impact with the most extensive range, but PTS represents the most significant and permanent impairment, making it the key impact threshold.

Since impact piling is an impulsive noise source that is likely to propagate more than 3.5 km from the source, this study considered the impulsive and non-impulsive sound criteria for marine mammal PTS and TTS thresholds from Southall *et al.* (2019), which is summarised in Table 2-2 and Table 2-3.

Table 2-2: Peak SPL ($L_{p,pk}$) criteria for PTS and TTS in marine mammals (Southall et al., 2019)

Southall *et al.* (2019)	$L_{p,pk}$ (dB re 1 µPa)	
	Impulsive	
	PTS	TTS
Low-frequency cetaceans (LF)	219	213
High-frequency cetaceans (HF)	230	224
Very high-frequency cetaceans (VHF)	202	196
Phocid carnivores in water (PCW)	218	212

Table 2-3: Cumulative SEL ($L_{E,p,wtd}$) criteria for PTS and TTS in marine mammals (Southall et al., 2019)

Southall *et al.* (2019)	$L_{E,p,wtd}$ (dB re 1 µPa²s)			
	Impulsive		Non-impulsive	
	PTS	TTS	PTS	TTS
Low-frequency cetaceans (LF)	183	168	199	179
High-frequency cetaceans (HF)	185	170	198	178
Very high-frequency cetaceans (VHF)	155	140	173	153
Phocid carnivores in water (PCW)	185	170	201	181

2.3.2 Fish

2.3.2.1 Popper *et al.* (2014): Mortality, injury and behavioural effects

Popper *et al.* (2014) offers guidelines on underwater noise impacts to marine fauna (excluding marine mammals). Unlike earlier studies, it categorises fish based on physiological morphology, particularly swim bladder function, that affect hearing sensitivity and provides criteria for key anthropogenic sound sources. Marine faunae are grouped into sea turtles, eggs and larvae, and three fish hearing categories:

- Fish: no swim bladder
- Fish: swim bladder not involved in hearing
- Fish: Swim bladder involved in hearing.

Popper *et al.* (2014) then provides impact thresholds for each marine faunae category related to sound exposure, including:

- Mortality and potential mortal injury: immediate or delayed death.
- Impairment, such as:
    - Recoverable injury: injuries unlikely to result in mortality.
    - Temporary Threshold Shift (TTS): short or long-term changes in hearing sensitivity that may or may not reduce fitness.
    - Masking: Reduction in sound detectability due to the simultaneous presence of another sound.
- Behavioural effects: substantial change in behaviour for the animals exposed to a sound (long or short term).

Despite emerging evidence of fish sensitivity to particle motion (see Section 2.2.2), the Popper *et al.* (2014) criteria provide a quantitative criterion as thresholds for impact onsets in terms of sound pressure related functions (e.g., $L_{p,pk}$, $L_{p,RMS}$, $L_{E,p,t}$). For fish, both stationary and fleeing animal models are used for $L_{E,p,t}$ thresholds to account for species diversity and varying responses to noise. Most species in Popper *et al.* (2014) are likely to flee from harmful sounds (Dahl *et al.,* 2015), and these flee speeds are likely to vary widely across species. Therefore, a conservative fleeing speed of 1.5 ms^{-1} (Hirata, 1999) is used in fleeing animal models. However, some species in Popper *et al.* (2014) have lower sensitivity not sound, such as benthic or swim bladderless species, remain stationary even when exposed to high intensity sounds (e.g., Goertner *et al.,* 1994, 1978; Stephenson *et al.,* 2010; Halvorsen *et al.,* 2012). Therefore, to avoid overestimating risk, a combined approach, which presents both fleeing and stationary models, is used in this report.

When the available data is insufficient to provide a quantitative criterion, Popper *et al.* (2014) provides a relative assessment of risk, qualified as either high, moderate, or low, based on the receptor. These risks are assessed for three approximate distances relative to the sound source: the near-field (tens of meters), intermediate-field (hundreds of meters) or far-field (thousands of meters). This study uses the criteria from Popper *et al.* (2014) for pile driving, summarised in Table 2-4.

Table 2-4: Recommended guidelines for pile driving according to Popper et al. (2014) for fish, sea turtles and eggs and larvae (N = Near-field; I = Intermediate-field; F = Far-field).

Popper *et al.* (2014) criteria for Pile Driving					
Type of fish	**Mortality and potential mortal injury**	**Impairment**			**Behaviour**
		Recoverable injury	**TTS**	**Masking**	
Fish: no swim bladder	**>219 $L_{E,p}$** **>213 $L_{p,pk}$**	**>216 $L_{E,p}$** **>213 $L_{p,pk}$**	**>>186 $L_{E,p}$**	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	**210 $L_{E,p}$** **>207 $L_{p,pk}$**	**203 $L_{E,p}$** **>207 $L_{p,pk}$**	**>186 $L_{E,p}$**	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing	**207 $L_{E,p}$** **>207 $L_{p,pk}$**	**203 $L_{E,p}$** **>207 $L_{p,pk}$**	**186 $L_{E,p}$**	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
Sea Turtles	**210 $L_{E,p}$** **>207 $L_{p,pk}$**	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low
Eggs and Larvae	**>210 $L_{E,p}$** **>207 $L_{p,pk}$**	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low

3 Underwater Noise Modelling: Methodology

Modelling of underwater noise is complex and can be approached in several different ways. To estimate the noise levels generated by the impact piling activities, Subacoustech have chosen to utilise dBSea (software version 2.4.28), a commercially available software developed by Marshall Day Acoustics designed to predict underwater noise which uses various numerical solvers to calculate underwater noise. For this project, two different solvers were used:

- A parabolic equation (PE) method for lower frequencies (12.5 Hz to 250 Hz)
    - Widely used within the underwater acoustics community but has computational limitations at high frequencies.
- A ray tracing method for higher frequencies (315 Hz to 100 kHz).
    - More computationally efficient at higher frequencies but is not suited to low frequencies (Etter, 1991).

The model incorporates bathymetry data and noise sources, with user-defined seabed and water properties (e.g. sound speed, temperature, salinity, current). Using selected numerical solvers, the software calculates 1/3rd octave band noise levels between 12.5 Hz – 100 kHz at set distances across the defined area, considering inputted environmental parameters and source characteristics.

3.1 Input Parameter

3.1.1 Modelling Location

One skid structure was provided by the client as a representative modelling location. To stay within the modelling software's capabilities, the 24 m subsea pile was represented as a point source at its midpoint, 12 m above the seabed at 79 m depth. Details of the noise source location used are presented in Table 3-1.

Table 3-1: Details of the modelling locations. Latitude/Longitude are in ED50.

Modelling location	Latitude	Longitude	Source depth below surface (m)	Depth at source location (m)
Skid Structure	56°53'0.43"N	1°13'49.04"E	79	91

3.1.2 Bathymetry

The bathymetry data used in the modelling was obtained from The European Marine Observation and Data Network (EMODnet, 2018). This data has a resolution of 1/16th arcminutes (approximately 115 × 115 m). The bathymetry used for modelling covers an area of 100 km × 100 km surrounding the modelling location.

3.1.3 Seabed Properties

Characteristics of the seabed were based on local data supplied by the Marine Scotland National Marine Plan Interactive (NMPi) tool. The seabed in the area is assumed to be comprised of a 50 m sediment layer of sand, which is above a bedrock layer of sandstone. Geo-acoustic properties for the seabed were based on available data from Jensen *et al*. (1994, 2011), which are provided in Table 3-2.

Table 3-2: Seabed geo-acoustic properties of the area.

Material	Compressive sound speed profile in substrate (ms^{-1})	Density profile in substrate (kgm^{-3})	Attenuation profile in substrate (dB/wavelength)
Sand	1,650	1,900	0.8
Sandstone	3,000	2,500	0.1

3.1.4 Sound Speed Profile

The speed of sound in the water has been calculated for the average annual temperature and salinity using the Mackenzie (1981) equation, with data from the Marine Scotland for the modelling location. The resulting profile is shown in Figure 3-1.

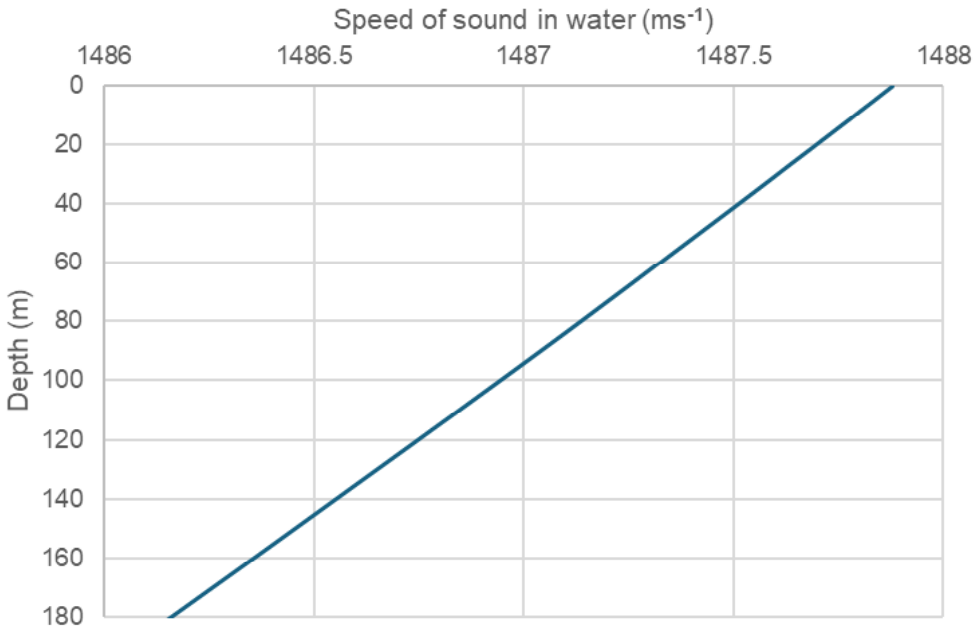


Figure 3-1: Sound speed profile used for detailed modelling of the area.

3.1.5 Noise Source

To carry out detailed noise modelling, a source spectrum and estimated source levels for $L_{p,pk}$ and $L_{E,p,ss}$ (single strike) from the noise source must be used. To calculate source levels, piling specifications are required, which were provided by the client:

- Pile type:
  - Diameter: 0.61 m (24-inch) diameter x 24 m length, installed to a depth of 20 m.
  - Maximum hammer blow energy: 90 kJ
- Total duration:
  - Piling will take place for a maximum of 8 hours per day:
    - It will take 2 hours of piling to install one pile.
    - 4 piles are proposed to be installed per 24-hour period.

- Piling schedule, including soft start:
    - 15 blows at 30% energy (27 kJ), delivered at a strike rate of 6 strikes per minute, over a period of 2.5 minutes
    - 15 blows at 60% energy (54 kJ), delivered at a strike rate of 6 strikes per minute, over a period of 2.5 minutes
    - 5,750 blows at 100% energy (90 kJ), delivered at a strike rate 50 strikes per minute, over a period of 1 hour and 55 minutes.

Within a 24-hour period, this schedule is repeated 4 times (once for each pile), giving a total maximum piling duration of 8 hours. It should be noted that because this project is not yet at the detailed design stage, specific soft start parameters are not currently known, and therefore, the modelled parameters are based on those used for similar projects. These details are summarised in Table 3-3 below.

Table 3-3: Summary of the piling procedure used for the modelling

Blow energy	30% (27 kJ)	60% (54 kJ)	100% (90 kJ)
No. of strikes	15	15	5,750
Duration (mins)	2.5	2.5	115
Strike rate (str/min)	6	6	50
5,780 strikes over 2 hours per pile 23,120 strikes over 8 hours for four sequentially installed piles			

Source levels were extrapolated from direct measurements of impact piling using, taken by Subacoustech Environmental (Midforth and East, 2019), which used similar pile sizes and blow energies. The apparent source levels used in modelling are presented in Table 3-4.

Table 3-4: Summary of the $L_{p,pk}$ and $L_{E,p,ss}$ source levels for different impact piling energies used in the piling sequence.

Blow energy	Apparent source level @ 1 m	
	$L_{p,pk}$ (dB re 1 µPa)	$L_{E,p,ss}$ (dB re 1 µPa^{2}s)
30% (27 kJ)	204.2	189.6
60% (54 kJ)	211.9	192.7
100% (90 kJ)	216.7	194.8

To carry out detailed noise modelling, a source spectrum for each noise source was used from relevant measured data taken by Subacoustech of piling at Portsmouth Harbour using similar pile sizes and blow energies (Midforth and East, 2019). From this measured data, the 1/3rd octave levels were then adjusted to achieve the required source levels and peak frequencies for each noise source (values stated in Table 3-4). An example of the 1/3rd octave source spectrum for the impact piling at 100% energy is shown in Figure 3-2, which was adjusted for each impact piling energy according to the associated approximate source level stated in Table 3-4.

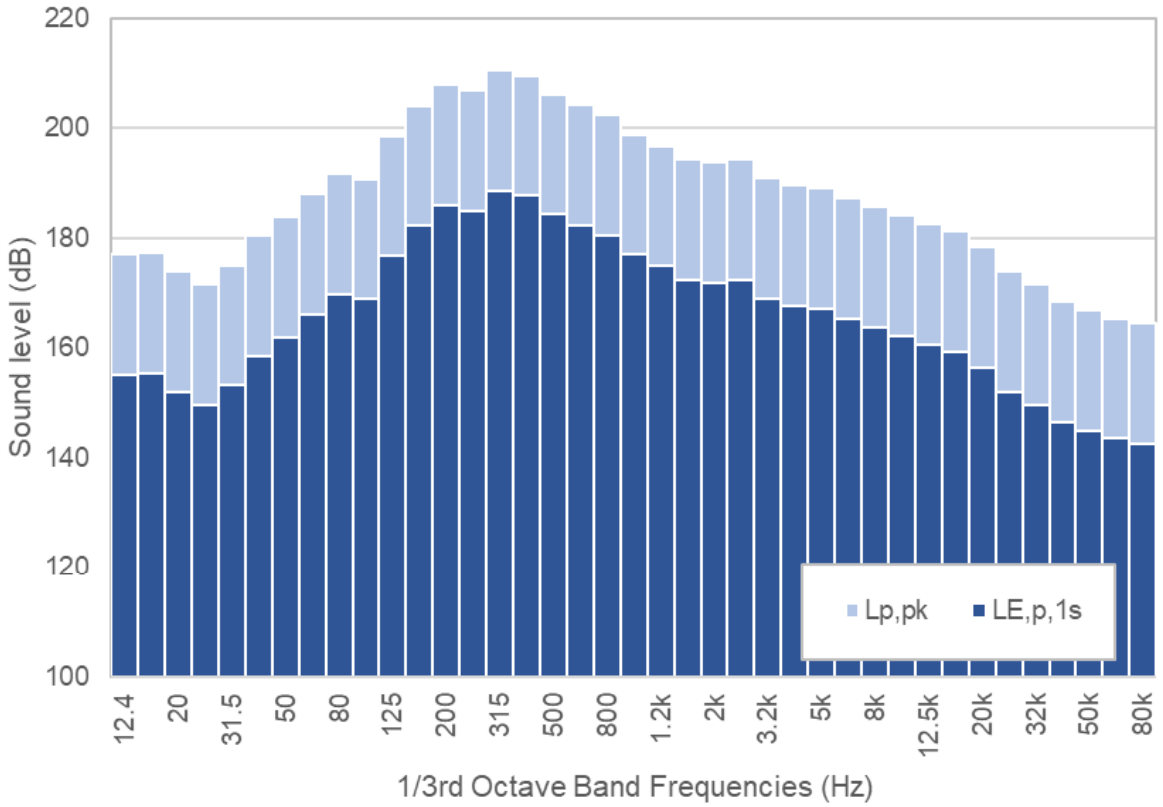


Figure 3-2: An example of the source spectrum containing 1/3rd octave band levels used to model impact piling at 100% energy.

To calculate $L_{E,p,24h}$ from $L_{E,p,ss}$, the total number of strikes at each energy per 24-hour period, presented in Table 3-3, was accounted for, as per Equation 4 (Section 2.1.2.2).

4 Underwater Noise Modelling: Results

The distribution of noise from impact piling noise are presented as noise contour plots in the following section. These noise contours are then interpreted into impact ranges using the relevant criteria from Southall *et al.* (2019) for marine mammals, and Popper *et al.* (2014) for fish.

4.1 Model Validation

A common practice in underwater noise studies of impact piling is to report noise levels at 750 m. This standard distance enables consistent comparison with other models and measurement data, as it lies beyond nearfield effects and mitigation zones where propagation patterns are stable and measurements are more reliable than levels measured at the source (for example, von Pein *et al*., 2022). A summary of the modelled unweighted levels at a range of 750 m are given in Table 4-1 considering the transect with the greatest noise transmission.

Table 4-1: Summary of the predicted maximum $L_{p,pk}$ and $L_{E,p,ss}$ across all modelled transects at 750 m range for different impact piling energies used in the piling sequence.

Blow energy	Predicted Maxium Level @ 750 m	
	$L_{p,pk}$ (dB re 1 µPa)	$L_{E,p,ss}$ (dB re 1 µPa^{2}s)
30% (27 kJ)	163.6	148.7
60% (54 kJ)	171.3	151.8
100% (90 kJ)	176.1	153.9

4.2 Predicted Noise Levels

The distribution of noise from the impact piling activities is presented as noise contour plots in Figure 4-1 to Figure 4-4 representing $L_{p,pk}$ and $L_{E,p,ss}$. These plots show the maximum predicted noise level in the water column projected to the surface.

Figure 4-1 represents the $L_{p,pk}$ noise levels generated by the first strike in the impact piling sequence at 30% energy, and Figure 4-2 represents the noise levels at 100% energy, as the highest, and therefore worst-case energy. Figure 4-3 and Figure 4-4 represent the same but for the $L_{E,p,ss}$ metric. Noise levels generated from the total strikes across all three energies were used to calculate the $L_{E,p,24hr}$ for each piling sequence.

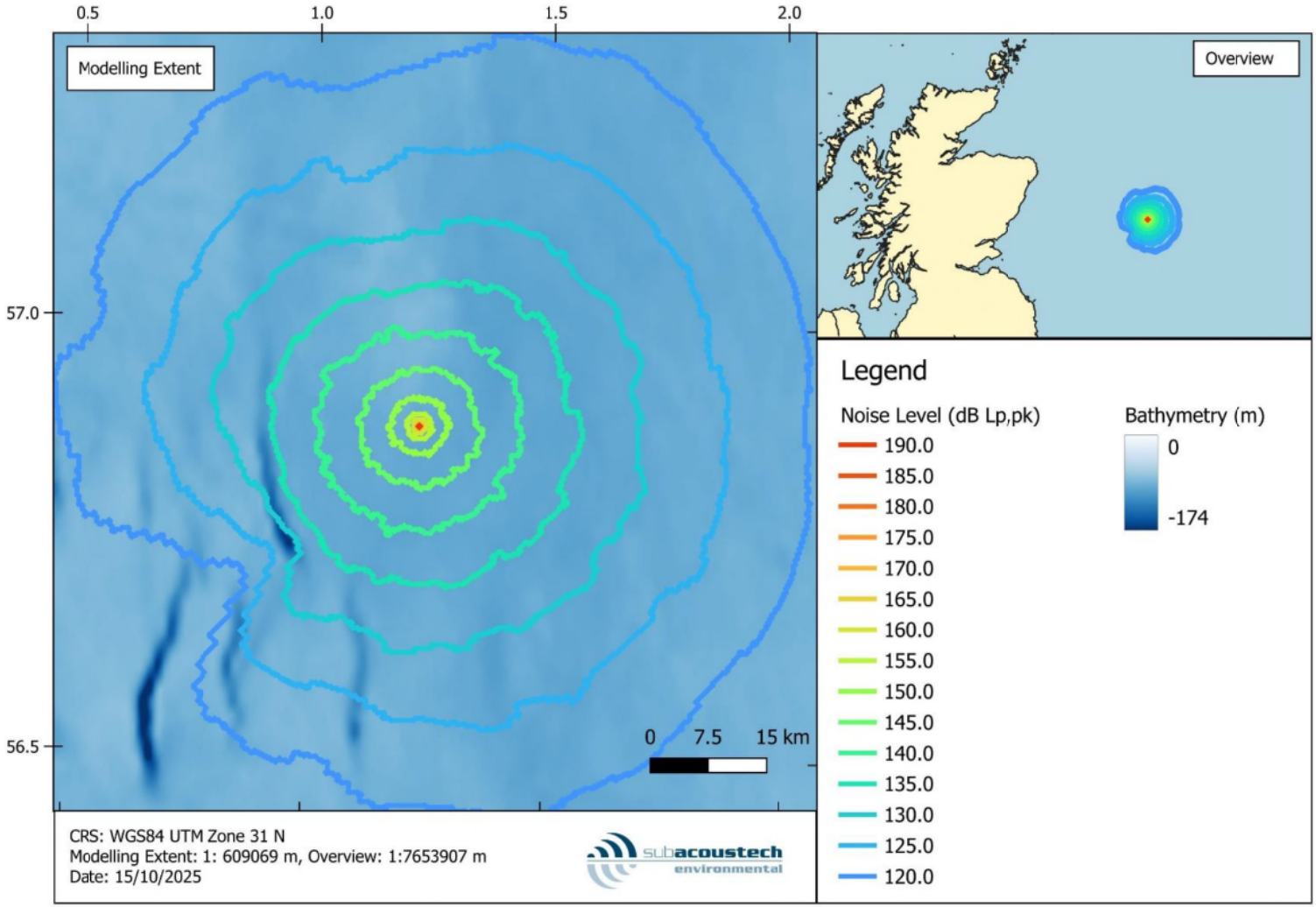


Figure 4-1: $L_{p,pk}$ contours predicted for impact piling at 30% energy (27 kJ).

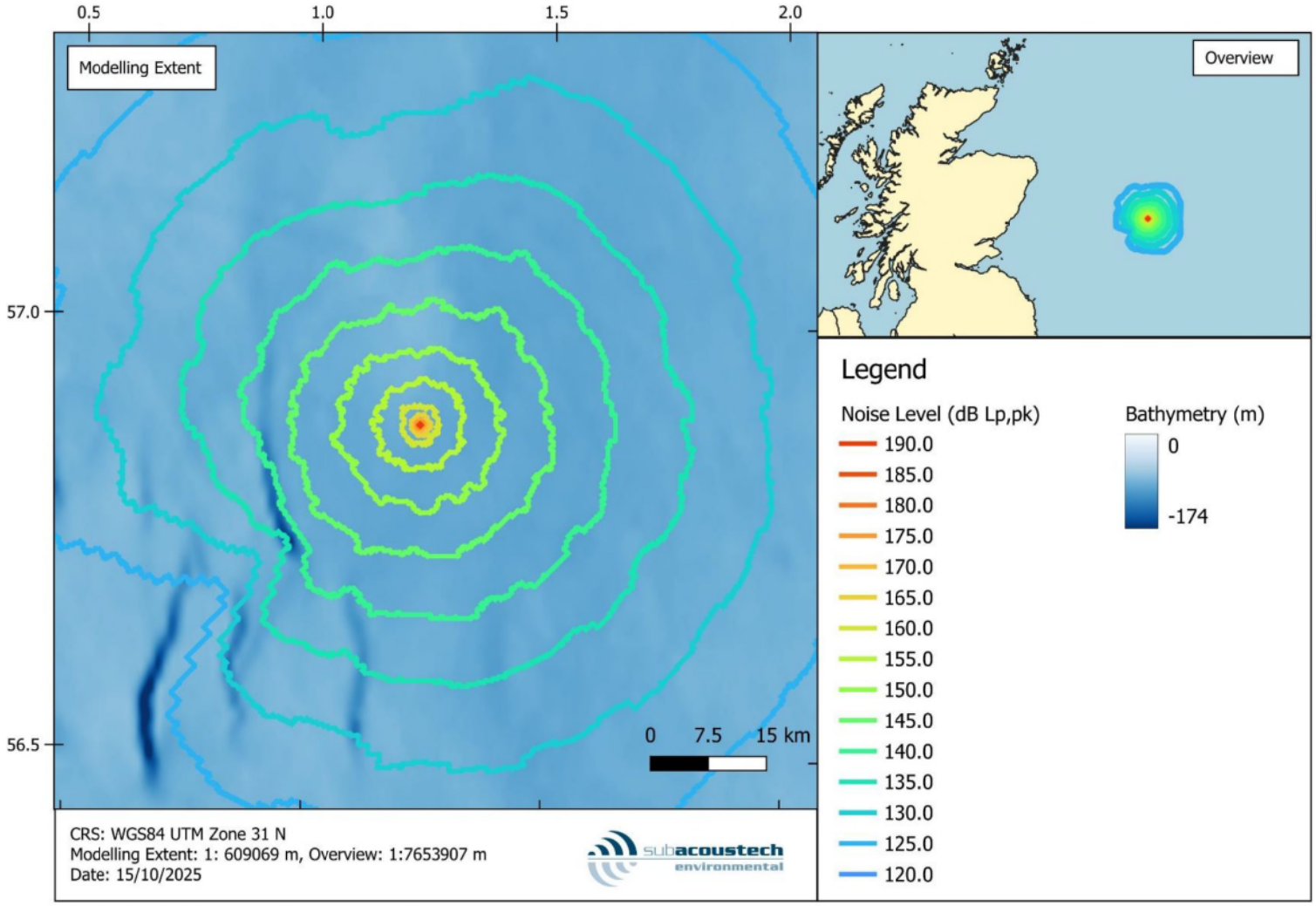


Figure 4-2: $L_{p,pk}$ contours predicted for impact piling at 100% energy (90 kJ)

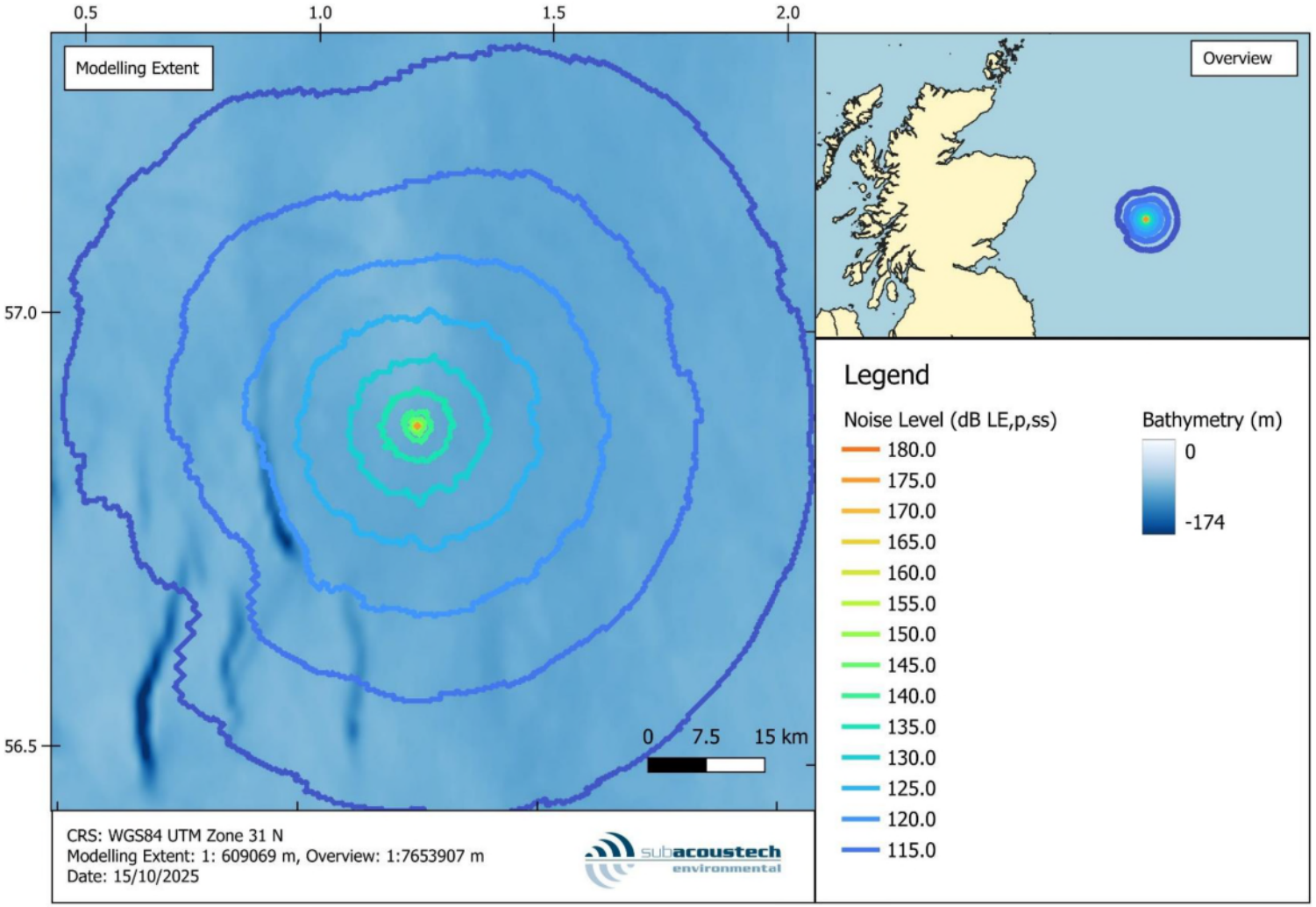


Figure 4-3: $L_{E,p,ss}$ (single strike) contours predicted for impact piling at 30% energy (27 kJ).

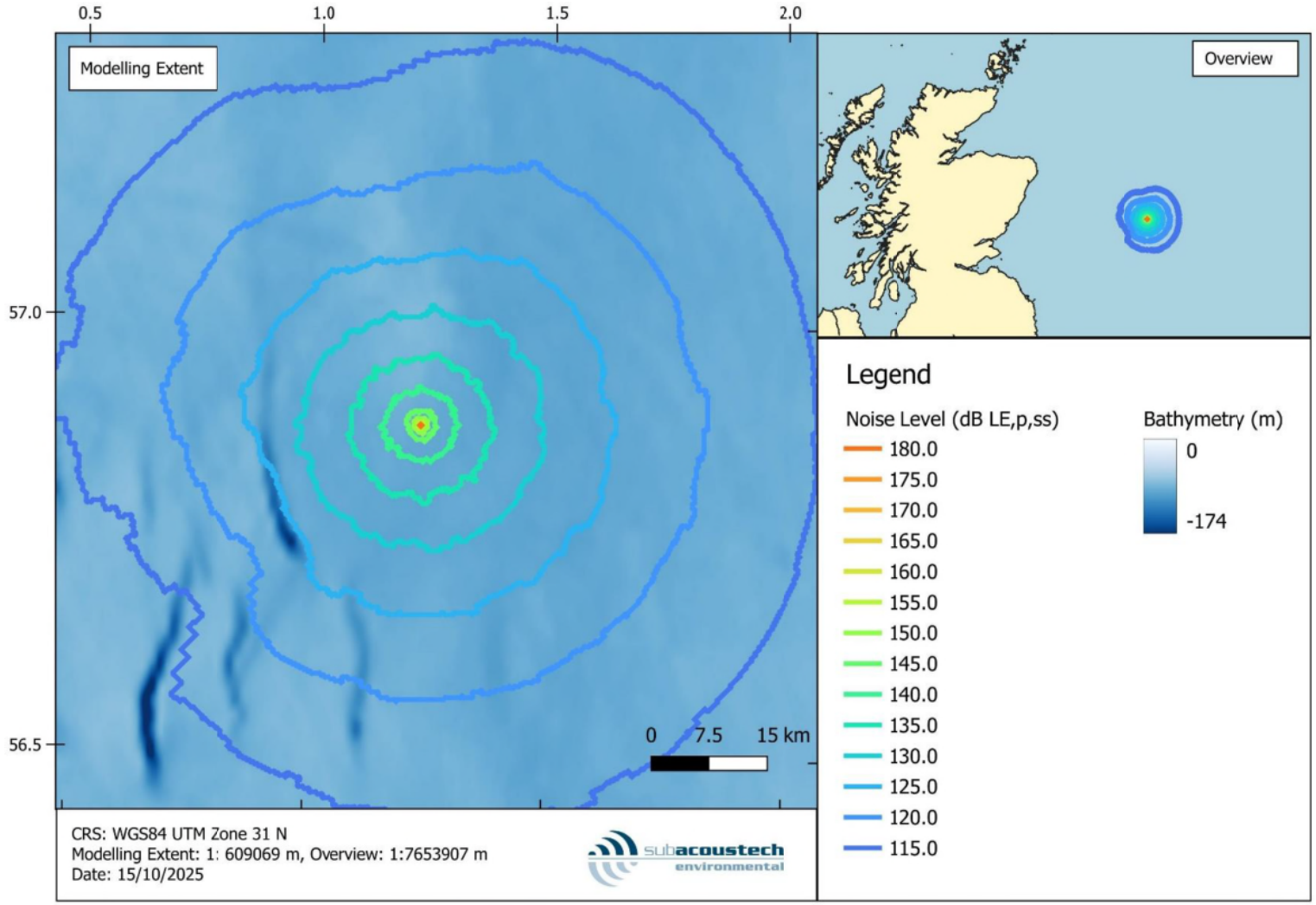


Figure 4-4: $L_{E,p,ss}$ (single strike) contours predicted for impact piling at 100% energy (90 kJ).

4.3 Interpretation

Due to the complexity in noise conditions at close range to the source, estimated impact ranges are limited to a resolution of 10 m from the source, as such, ranges smaller than this have been presented as "< 10 m". Any impact range noted as NE indicates that no exceedance is expected for the given criteria based on the results of the modelling.

4.3.1 Assessment: Marine Mammals

The noise level results from Section 4.2 were weighted and assessed against the Southall *et al.* (2019) guidelines to predict the likely range at which the thresholds for impulsive and non-impulsive sounds would be exceeded by marine mammals.

4.3.1.1 $L_{p,pk}$ criteria

Using the predicted $L_{p,pk}$ noise contours (Figure 4-1 and Figure 4-2) to calculate the $L_{p,pk}$ impacts using the Southall *et al*. (2019) criteria, it is unlikely that animals will exceed the PTS threshold at any range from the impact piling activities at the first strike of the soft start at 30% energy. At maximum energy, the PTS ranges are predicted out to 20 m for VHF cetaceans. These details, along with TTS impact ranges predicted across all groups, are presented in Table 4-2 and Table 4-3.

Table 4-2: Estimated impact ranges for impact piling activities at 30% energy using the Southall et al. (2019) $L_{p,pk}$ marine mammal criteria for impulsive noise sources.

Southall *et al*. (2019) criteria $L_{p,pk}$ (Impulsive)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
LF Cetaceans	PTS	219 dB	NE	NE	NE
	TTS	213 dB	NE	NE	NE
HF Cetaceans	PTS	230 dB	NE	NE	NE
	TTS	224 dB	NE	NE	NE
VHF Cetaceans	PTS	202 dB	< 10	< 10	< 10
	TTS	196 dB	< 10	< 10	< 10
PCW Pinnipeds	PTS	218 dB	NE	NE	NE
	TTS	212 dB	NE	NE	NE

NE = No predicted exceedance

Table 4-3: Estimated impact ranges for impact piling activities at 100% energy using the Southall et al. (2019) $L_{p,pk}$ marine mammal criteria for impulsive noise sources.

Southall *et al.* (2019) criteria $L_{p,pk}$ (Impulsive)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
LF Cetaceans	PTS	219 dB	NE	NE	NE
	TTS	213 dB	< 10	< 10	< 10
HF Cetaceans	PTS	230 dB	NE	NE	NE
	TTS	224 dB	NE	NE	NE
VHF Cetaceans	PTS	202 dB	20	20	20
	TTS	196 dB	40	40	40
PCW Pinnipeds	PTS	218 dB	NE	NE	NE
	TTS	212 dB	< 10	< 10	< 10

NE = No predicted exceedance

4.3.1.2 $L_{E,p,t}$ criteria

The predicted $L_{E,p,ss}$ (single strike) levels (Figure 4-3 and Figure 4-4) were combined using the piling sequency detailed in Table 3-3, species weightings and fleeing animal assumptions to calculate PTS and TTS ranges in terms of $L_{E,p,24hr,wtd}$. Based on the impulsive noise $L_{E,p,wtd}$ criteria from Southall *et al.* (2019), animals would need to be within 10 m of piling activities to exceed the PTS thresholds. These details, along with TTS impact ranges and non-impulsive criteria ranges, are presented in Table 4-4 and Table 4-5.

Table 4-4: Estimated impact ranges for the impact piling activities using the Southall et al. (2019) $L_{E,p,wtd}$ marine mammal criteria for impulsive noise sources assuming a fleeing animal.

Southall *et al.* (2019) criteria $L_{E,p,wtd}$ (Impulsive)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
LF Cetaceans	PTS	183 dB	10	10	10
	TTS	168 dB	8,800	8,000	6,800
HF Cetaceans	PTS	185 dB	< 10	< 10	< 10
	TTS	170 dB	< 10	< 10	< 10
VHF Cetaceans	PTS	155 dB	10	10	10
	TTS	140 dB	3,400	3,200	2,900
PCW Pinnipeds	PTS	185 dB	10	10	10
	TTS	170 dB	70	40	20

Table 4-5: Estimated impact ranges for the impact piling activities using the Southall et al. (2019) $L_{E,p,wtd}$ marine mammal criteria for non-impulsive noise sources assuming a fleeing animal.

Southall *et al.* (2019) criteria $L_{E,p,wtd}$ (Non-Impulsive)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
LF Cetaceans	PTS	199 dB	< 10	< 10	< 10
	TTS	179 dB	80	50	30
HF Cetaceans	PTS	198 dB	< 10	< 10	< 10
	TTS	178 dB	< 10	< 10	< 10
VHF Cetaceans	PTS	173 dB	< 10	< 10	< 10
	TTS	153 dB	30	20	10
PCW Pinnipeds	PTS	201 dB	< 10	< 10	< 10
	TTS	181 dB	< 10	< 10	< 10

4.3.2 Assessment: Fish

The noise level results from Section 4.2 were assessed against the Popper *et al.* (2014) guidelines to predict the likely range at which the thresholds for impact piling would be exceeded by fish.

4.3.2.1 $L_{p,pk}$ criteria

Table 4-6 and Table 4-7 show that using the $L_{p,pk}$ criteria, it is unlikely that animals will exceed the any of the thresholds for fish at any distance from the impact piling activities.

Table 4-6: Estimated impact ranges for the impact piling activities the Popper et al. (2014) $L_{p,pk}$ fish criteria for pile driving at 30% energy.

Popper *et al*. (2014) criteria $L_{p,pk}$ (Pile Driving)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
Fish: no swim bladder	Mortal and potential mortal injury	213 dB	< 10	< 10	< 10
	Recoverable injury		< 10	< 10	< 10
Fish: swim bladder not involved in hearing	Mortal and potential mortal injury	207 dB	< 10	< 10	< 10
	Recoverable injury		< 10	< 10	< 10
Fish: swim bladder involved in hearing	Mortal and potential mortal injury	207 dB	< 10	< 10	< 10
	Recoverable injury		< 10	< 10	< 10

Table 4-7: Estimated impact ranges for the impact piling activities the Popper et al. (2014) $L_{p,pk}$ fish criteria for pile driving at 100% energy.

Popper *et al*. (2014) criteria $L_{p,pk}$ (Pile Driving)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
Fish: no swim bladder	Mortal and potential mortal injury	213 dB	< 10	< 10	< 10
	Recoverable injury		< 10	< 10	< 10
Fish: swim bladder not involved in hearing	Mortal and potential mortal injury	207 dB	< 10	< 10	< 10
	Recoverable injury		< 10	< 10	< 10
Fish: swim bladder involved in hearing	Mortal and potential mortal injury	207 dB	< 10	< 10	< 10
	Recoverable injury		< 10	< 10	< 10

4.3.2.2 $L_{E,p,t}$ criteria

The predicted unweighted $L_{E,p,ss}$ for each blow energy were combined to calculate the total $L_{E,p,24hr}$. Using the $L_{E,p,t}$ criteria for pile driving from Popper *et al*. (2014), animals are unlikely to exceed injury thresholds if they flee at a constant speed for over the 8 hours of piling.

However, if the receptors are assumed to remain stationary for the entire 8-hour piling sequence, mortality and potential mortal injury ranges are expected to 180 m for fish with swim bladders involved in hearing. These details, along with the other calculated impact ranges predicted across all groups, are presented in Table 4-8 for fleeing animals, and Table 4-9 for stationary animals.

Table 4-8: Estimated impact ranges for the impact piling activities the Popper et al. (2014) $L_{E,p,24h}$ fish criteria for pile driving assuming a fleeing animal.

Popper *et al*. (2014) criteria $L_{E,p,24h}$ (Pile Driving)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
Fish: no swim bladder	Mortal and potential mortal injury	219 dB	< 10	< 10	< 10
	Recoverable injury	216 dB	< 10	< 10	< 10
	TTS	186 dB	10	10	10
Fish: swim bladder not involved in hearing	Mortal and potential mortal injury	210 dB	< 10	< 10	< 10
	Recoverable injury	203 dB	< 10	< 10	< 10
	TTS	186 dB	10	10	10
Fish: swim bladder involved in hearing	Mortal and potential mortal injury	207 dB	< 10	< 10	< 10
	Recoverable injury	203 dB	< 10	< 10	< 10
	TTS	186 dB	10	10	10

Table 4-9: Estimated impact ranges for the impact piling activities the Popper et al. (2014) $L_{E,p,24h}$ fish criteria for pile driving assuming a stationary animal.

Popper *et al*. (2014) criteria $L_{E,p,24h}$ (Pile Driving)			Estimated Impact Range (m)		
			Maximum	Mean	Minimum
Fish: no swim bladder	**Mortal and potential mortal injury**	219 dB	30	30	30
	Recoverable injury	216 dB	40	40	40
	TTS	186 dB	3,900	3,600	3,300
Fish: swim bladder not involved in hearing	**Mortal and potential mortal injury**	210 dB	110	110	100
	Recoverable injury	203 dB	310	310	300
	TTS	186 dB	3,900	3,600	3,300
Fish: swim bladder involved in hearing	**Mortal and potential mortal injury**	207 dB	180	180	170
	Recoverable injury	203 dB	310	310	300
	TTS	186 dB	3,900	3,600	3,300

5 Summary and Conclusions

Subacoustech Environmental, on behalf of Orbis Energy Ltd and their client Serica Energy Chinook Ltd, has undertaken an underwater noise modelling assessment in anticipation of offshore piling works taking place at the Kyle Oil Field, located in UKCS Block 29/2c in the central North Sea, UK. The works involve two valve skid structures, each comprising of four piles to be installed via impact piling. Piling activities will likely take place for a maximum of 8 hours per day. A soft start was also anticipated as part of the piling schedule.

The level of underwater noise generated by the survey was estimated in the dBSea software using a combined parabolic equation and ray tracing modelling approach. The modelling considers a wide array of input parameters including the equipment source level, sound frequency content, seabed properties and the sound speed profile in the water column. Full account is also taken of the bathymetry in the areas surrounding the piling area.

The modelled noise levels for all sources were then interpreted in accordance with the guidelines outlined in Southall *et al.* (2019) for marine mammals in relation to impulsive and non-impulsive noise sources and the Popper *et al.* (2014) guidelines for fish in relation to pile driving.

For marine mammals, any animals within 20 m of the piling when it is at 100% energy will exceed the VHF cetacean $L_{p,pk}$ PTS criteria. When total noise output is considered using the $L_{E,p,24hr}$ metric, including the soft start, the PTS threshold is unlikely to be exceeded by any animal. For fish, the greatest predicted distance for mortality or injury risk from total noise output is predicted at 180 m from the piling activities for fish with a swim bladder involve in hearing. The $L_{p,pk}$ threshold across all fish morphologies are unlikely to be exceeded at any range, for any hammer blow energy.

By its nature, mathematical modelling will produce results that indicate a precise range at which a criterion will be reached, but this does not reflect the inherent uncertainty in the physical processes, including many that change constantly under real world conditions. While the results present specific ranges at which each impact threshold is met based on the modelling results, the ranges should be taken as indicative in determining where environmental effects may occur in receptors during the proposed operations.

References

Bailey H, Thompson P (2006). *Quantitive analysis of bottlenose dolphin movement patterns and their relationship with foraging.* Journal of Animal Ecology 75: 456-465.

Dahl P H, de Jong C A, Popper A N (2015). *The underwater sound field from impact pile driving and its potential effects on marine life.* Acoustics Today, Spring 2015, Volume 11, Issue 2.

EMODnet Bathymetry Consortium (2018) *EMODnet digital bathymetry (DTM) 2018* [dataset]. Available at: https://dx.doi.org/10.12770/18ff0d48b2034a6594a95fd8b0ec35f6 (Accessed: 1st October 2025).

Etter P C (1991). *Underwater acoustic modelling: Principles, techniques and applications.* Elsevier Science Publishers Ltd, Essex. ISBN 1-85166-528-5.

Goertner J F, Wiley M L, Young G A, McDonald W W (1994). *Effects of underwater explosions on fish without swim bladders.* Naval Surface Warfare Center. Report No. NSWC/TR-76-155.

Goertner J F (1978). *Dynamical model for explosion injury to fish.* Naval Surface Weapons Center, White Oak Lab, Silver Spring, MD. Report No. NSWC/WOL.TR-76-155.

Halvorsen M B, Casper B C, Matthew D, Carlson T J, Popper A N (2012). *Effects of exposure to pile driving sounds on the lake sturgeon, Nila tilapia, and hogchoker.* Proc. Roy. Soc. B 279: 4705-4714.

Hastie G, Merchant N D, Götz T, Russell D J F, Thompson P, Janik V M (2019). *Effects of impulsive noise on marine mammals: Investigating range-dependent risk.*

Hastings M C, Popper A N (2005). *Effects of sound on fish.* Report to the California Department of Transport, under Contract No. 43A01392005, January 2005.

Hawkins A D, Popper A N (2017). *A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates.* ICES J. Mar. Sci. 74 (3), 635–651. doi: 10.1093/icesjms/fsw205

Hirata K (1999). *Swimming speeds of some common fish.* National Maritime Research Institute (Japan). Data sourced from Iwai T, Hisada M (1998). Fishes – Illustrated Book of Gakken (in Japanese). http://www.nmri.go.jp/oldpages2/eng/khirata/fish/general /speed/speede.htm (accessed 8th March 2017).

Jensen F B, Kuperman W A, Porter M B, Schmidt H (2011). *Computational Ocean Acoustics*. Modern Acoustics and Signal Processing. Springer-Verlag, NY. ISBN: 978-1-4419-8678-8.

Jensen F B, Kuperman W A, Porter M B, Schmidt H (1994). *Computational Ocean Acoustics.* Woodbury NW, AIP Press.

Kastelein R A, van de Voorde S, Jennings N (2018). *Swimming speed of a harbor porpoise (Phocoena phocoena) during playbacks of offshore pile driving sounds*. Aquatic Mammals. 2018, 44(1), 92-99, DOI 10.1578/AM.44.1.2018.92.

Mackenzie K V (1981). *Nine-term equation for the sound speed in the oceans*. J. Acoust. Soc. Am. 70(3), pp 807 812.

Marine Scotland (2025) *National Marine Plan Interactive* [online]. Version 1.6.8.125. Available at: https://marinescotland.atkinsgeospatial.com/nmpi/ (Accessed: 17 October 2025).

Marshall Day Acoustics, Irwin Carr Consulting (2024) *dBSea version 2.4.28* [software]. Underwater acoustic modelling and prediction tool. dBSea Ltd. Available at: https://www.dbsea.co.uk

Martin S B, Lucke K, Barclay D R (2020). *Techniques for distinguishing between impulsive and non- impulsive sound in the context of regulating sound exposure for marine mammals*. The Journal of the Acoustical Society of America 147, 2159.

Midforth F, East S (2019). *Noise Monitoring of piling operations in Portsmouth Harbour*. Subacoustech Report Ref P244R0101.

National Marine Fisheries Service (NMFS) (2024). *Update to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0): Underwater and In Air Criteria for Onset of Auditory Injury and Temporary Threshold Shifts.* U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-71, 182 p.

National Marine Fisheries Service (NMFS) (2018). *2018 Revisions to: Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum, NMFS OPR-59.

Nedelec S L, Campbell J, Radford A N, Simpson S D, Merchant N D (2016). *Particle motion: The missing link in underwater acoustic ecology.* Methods Ecol. Evol. 7, 836 – 842.

Popper A N, Hawkins A D (2019). *An overview in fish bioacoustics and the impacts of anthropogenic sounds on fishes*. Journal of Fish Biology, 1-22. DOI: 10.111/jfp.13948.

Popper A N, Hawkins A D (2018). *The importance of particle motion to fishes and invertebrates*. J. Acoust. Soc. Am. 143, 470 – 486.

Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W N (2014). *Sound exposure guidelines for Fishes and Sea Turtles.* Springer Briefs in Oceanography DOI 10. 1007/978-3-319-06659-2.

Radford C A, Montgomery J C, Caiger P, Higgs D M (2012). *Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts*. Journal of Experimental Biology, 215, 3429 – 3435. Rawlins J S P (1987). Problems in predicting safe ranges from underwater explosions. Journal of Naval Science, Volume 14, No. 4 pp. 235-246.

Scottish Natural Heritage (SNH) (2016). *Assessing collision risk between underwater turbines and marine wildlife*. SNH guidance note.

Solé M, Kaifu K, Mooney T A, Nedelec S L, Olivier F, Radford A N, Vazzana M, Wale M A, Semmens J M, Simpson S D, Buscaino G, Hawkins A, Aguilar de Soto N, Akamatsu T, Chauvaud L, Day R D, Fitzgibbon Q, McCauley R D, André M (2023). *Marine invertebrates and noise*. Frontiers in Marine Science, 10.

Southall B L (2021). *Evolutions in Marine Mammal Noise Exposure Criteria.* Acoustics Today 17(2) https://doi.org/10.1121/AT.2021.17.2.52.

Southall B L, Finneran J J, Reichmuth C, Nachtigall P E, Ketten D R, Bowles A E, Ellison W T, Nowacek D P, Tyack P L (2019). *Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects.* Aquatic Mammals 2019, 45(2), 125-232, DOI 10.1578/AM.45.2.2019.125.

Stephenson J R, Gingerich A J, Brown R S, Pflugrath B D, Deng Z, Carlson T J, Langeslay M J, Ahmann M L, Johnson R L, Seaburg A G (2010). *Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory.* Fisheries Research Volume 106, Issue 3, pp 271-278, December 2010.

von Pein J, Lippert T, Lippert S, von Estorff O (2022). *Scaling laws for unmitigated pile driving: Dependence of underwater noise on strike energy, pile diameter, ram weight, and water depth.* Applied Acoustics 198 (2022) 108986.

Appendix E: Quantification of GHG Emissions

E.1 Introduction

This appendix sets out the methodology used to calculate the quantity of GHG emissions estimated to be generated from the proposed Kyla Development over the life of the field and supports the assessment documented in Section 9 (GHG Emissions) of the ES.

E.2 Direct GHG Emissions

E.2.1 Scope 1 Emissions (Processing of Kyla Hydrocarbons)

Once Kyla is online, Kyla production fluids will be processed offshore at the Triton FPSO. Incremental GHG emissions will be generated at the Triton FPSO, arising from the power generation requirements to treat the Kyla hydrocarbons (fuel gas is used to power the compressors and turbines) and from venting.

Calculation Methodology

The following equations have been used to calculate the incremental GHG emissions generated at the Triton FPSO as a result of Kyla coming online:

1. $GHG\ Emissions_{FUEL} = Fuel\ Gas\ used\ to\ power\ GTG \times GHG\ Conversion\ Factor$
2. $GHG\ Emissions_{VENT} = Volume\ of\ Gas\ Vented\ \times GHG\ Conversion\ Factor$

Therefore,

$$Total\ GHG\ Emissions = GHG\ Emissions_{FUEL} + GHG\ Emissions_{VENT}$$

Table E.1 lists the GHG conversion factors which have been used to calculate GHG emissions generated from fuel gas used to power the Gas Turbine Generators (GTG) and from venting (non-routine, with the primary source of venting on Triton from crude oil tanks) at the Triton FPSO.

Table E.1: GHG Conversion Factors for Fuel Use and Flaring at the Triton FPSO (EEMS, 2008)

Emission Factor Source	Triton FPSO Activity	GHG Conversion Factors (tonnes)			
		CO_2	N_2O	CH_4	CO_2e
'Gas Consumption Plant' (EEMS, 2008)	Fuel Gas (GTG)	2.86	0.00022	0.00092	Note [1]
'Gas Venting' (EEMS, 2008)	Venting from Crude Oil Tanks	0	0	0.9	Note [1]

[1] The GWPs used in the calculation of CO_2e are based on the IPCC Fifth Assessment Report (AR5).

Quantification of Scope 1 Emissions

Table E.2 details the incremental GHG emissions generated at the Triton FPSO as a result of Kyla coming online, assuming the Triton FPSO continues to operate as normal (i.e. powered by 2 x 42 MW GTG). GHG emissions have been calculated for all Kyla hydrocarbon profiles, namely high (P10), mid (P50) and low (P90) production cases.

Table E.2: Kyla Incremental Emissions at Triton FPSO

Year	Vent (kt/yr)	Fuel Gas (kt/yr)	Total Emissions (kt) [1]			
			CO_2	N_2O	CH_4	CO_2e
High Case (P10)						
2028	0.05	0.17	0.48	0.00	0.04	1.64
2029	0.30	1.10	3.16	0.00	0.27	10.85
2030	0.26	0.92	2.64	0.00	0.23	9.23
2031	0.21	0.73	2.09	0.00	0.19	7.36
2032	0.18	0.62	1.77	0.00	0.16	6.26
2033	0.15	0.54	1.54	0.00	0.14	5.46
2034	0.14	0.49	1.40	0.00	0.13	4.97
2035	0.13	0.45	1.29	0.00	0.12	4.61
Total	**1.41**	**5.03**	**14.37**	**0.00**	**1.27**	**50.36**
Year	**Vent (kt/yr)**	**Fuel Gas (kt/yr)**	**Total Emissions (kt) [1]**			
			CO_2	N_2O	CH_4	CO_2e
Mid Case (P50)						
2028	0.04	0.15	0.44	0.00	0.04	1.50
2029	0.23	0.84	2.41	0.00	0.21	8.39
2030	0.20	0.69	1.98	0.00	0.18	6.98
2031	0.15	0.52	1.48	0.00	0.13	5.29
2032	0.12	0.41	1.17	0.00	0.11	4.18
2033	0.10	0.34	0.96	0.00	0.09	3.46
2034	0.09	0.30	0.85	0.00	0.08	3.07
2035	0.08	0.28	0.79	0.00	0.07	2.85
Total	**1.01**	**3.53**	**10.09**	**0.00**	**0.91**	**35.72**
Year	**Vent (kt/yr)**	**Fuel Gas (kt/yr)**	**Total Emissions (kt) [1]**			
			CO_2	N_2O	CH_4	CO_2e
Low Case (P90)						
2028	0.01	0.05	0.15	0.00	0.01	0.50
2029	0.09	0.32	0.93	0.00	0.08	3.12
2030	0.08	0.30	0.87	0.00	0.07	2.93
2031	0.08	0.29	0.83	0.00	0.07	2.81
2032	0.08	0.29	0.83	0.00	0.07	2.79
2033	0.07	0.28	0.80	0.00	0.07	2.71
2034	0.07	0.28	0.80	0.00	0.07	2.71
2035	0.08	0.28	0.81	0.00	0.07	2.74
Total	**0.56**	**2.10**	**6.02**	**0.00**	**0.51**	**20.31**

[1] Refer to GHG conversion factors in Table E.1.

E.3 Indirect GHG Emissions

E.3.1 Upstream Scope 3 Emissions (Offshore Operations)

Upstream scope 3 emissions are the indirect emissions which will be generated by Serica's contractors offshore when extracting, producing and exporting Kyla hydrocarbons to the Triton FPSO, as well as during decommissioning operations upon cessation of production.

Calculation Methodology

The following equation has been used to calculate the total quantity of upstream scope 3 emissions generated from the Kyla development offshore operations:

$$GHG\ Emissions = Activity\ (Fuel\ Consumption) \times GHG\ Conversion\ Factor$$

Table E.3 lists the GHG conversion factors which have been used to calculate GHG emissions generated from offshore transport related activity (i.e. vessel and helicopter movements).

Table E.3: GHG Conversion Factors for Fuel used in Transport Activities (DESNZ, 2025e)

Fuel	Kyla Activity	GHG Conversion Factors (kg CO_2e of GHG per unit)			
		CO_2	N_2O	CH_4	CO_2e [1]
'Marine Gas Oil'	Vessels	3205.99000	38.40721	0.90720	3245.30441
'Aviation Turbine Fuel'	Helicopters	3149.67000	26.50000	2.19520	3178.3652

[1] The GWPs used in the calculation of CO_2e are based on the IPCC Fifth Assessment Report (AR5).

Quantification of Total Upstream Scope 3 Emissions

Table E.4: Kyla Total Upstream Scope 3 Emissions (Offshore Operations)

Kyla Activity	Total Fuel Use (tonnes) [1]	GHG Emissions (tonnes) [2]			
		CO_2	N_2O	CH_4	CO_2e
Drilling Operations	7,539.00	24,164.72	213.09	6.77	24,384.58
Installation Operations	4,504.00	14,439.78	111.53	4.09	14,555.40
Inspection and Maintenance Operations	1,000.00	3,205.99	38.41	0.91	3,245.30
Decommissioning Operations	3,401.00	10,902.33	99.35	3.07	11,004.75
Total:		**52,712.82**	**462.38**	**14.83**	**53,190.04**

[1] Total fuel use based on vessel and helicopter requirements for drilling operations (Table 3.1), installation operations (Table 3.11), inspection and maintenance operations (Table 3.17), and decommissioning operations (Table 3.18), as detailed in Section 3.
[2] Refer to GHG conversion factors in Table E.3.

E.3.2 Downstream Scope 3 Emissions (Further Refinement, Transportation and Distribution and End Use of Sold Products)

Downstream scope 3 emissions are the indirect emissions which will be generated once the Kyla hydrocarbons have been processed to export specification at Triton and sold, including from transportation and distribution, as well as from the end use of the sold product (namely, the presumption that all end use Kyla hydrocarbons are eventually combusted). Of note, oil from Triton is typically tankered to Rotterdam where oil volumes are integrated into the wider European oil sales market. Gas from Triton is piped to the St Fergus terminal where it enters the UK's national distribution system.

Further Refinement, Transportation and Distribution

Calculation Methodology

Well-to-Tank (WTT) emissions represent the GHG emissions generated during the extraction, refinement, transport and distribution of fuels prior to their end-use. In a downstream context, this includes all emissions associated with the handling and logistical operations required to deliver refined hydrocarbons to market, but excludes combustion or end-use emissions, which are quantified separately below.

The following equation has been used to calculate the total quantity of GHG emissions generated from the further refinement, transportation and distribution of Kyla hydrocarbons:

$$GHG\ Emissions = Production\ (Oil\ or\ Gas) \times GHG\ Conversion\ Factor$$

Table E.5 details the GHG conversion factors used to calculate the WTT emissions. 'Natural gas (100% mineral blend)' has been assumed as the downstream proxy fuel for Kyla gas, and 'fuel oil' has been assumed as the downstream proxy fuel for Kyla oil.

Table E.5: Well-to-Tank GHG Conversion Factors (DESNZ, 2025e)

Kyla Hydrocarbon	Downstream Proxy Fuel	GHG Conversion Factor (kg CO_2e of GHG per unit)
Oil	'Fuel Oil' WTT Fuels [1]	714.86545
Gas	'Natural gas (100% mineral blend)' WTT Fuels	423.16368

[1] 'Fuel Oil' has been used as a proxy as it is considered to most closely match oil for the purposes of this assessment.

As the WTT GHG conversion factors encompass the emissions associated with the extraction, refining and transportation of hydrocarbons prior to their end use, these already account for the incremental emissions that would be generated at Triton FPSO as a result of Kyla coming online (as presented in Section H.2). Therefore, to prevent double-counting, the Kyla Scope 1 baseline emissions have been deducted from the total calculated WTT emissions. This adjustment ensures that only the downstream GHG emissions associated with the further refinement, transport and distribution of hydrocarbons beyond the Triton FPSO are represented within the WTT total.

However, given the nature of the Kyla hydrocarbons and the known stages of refinement prior to transport and distribution to market, particularly as gas exported from the St Fergus Gas Terminal feeds directly into the NTS, the quantity of CO_2e emissions calculated for the Further Refinement, Transportation and Distribution phase is likely to be a conservative estimate.

Quantification of GHG Emissions

Table E.6: Kyla Development WTT Scope 3 Emissions

Kyla Hydrocarbon	Total Quantity of Produced Hydrocarbons (kt) [1]	CO_2e Emissions (kt) [2]
High Case (P10)		
Kyla Oil	1,586.43	1,134.09
Kyla Gas	255.88	108.28
High Case (P10) Total:	**1,842.31**	**1,242.36**
Mid Case (P50)		
Kyla Oil	1,130.06	807.84
Kyla Gas	179.60	76.00
Mid Case (P50) Total:	**1,309.66**	**883.84**
Low Case (P90)		
Kyla Oil	629.69	450.14
Kyla Gas	107.15	45.34
Low Case (P90) Total:	**736.83**	**495.48**

[1] Refer to Appendix G for Kyla production profiles. Gas converted from m^3 to tonnes using a density of 1.066 kg/m^3.
[2] Refer to GHG conversion factors in Table E.5.

Table E.7: Kyla Further Refinement, Transportation and Distribution Emissions

Kyla Production Case	Field Life WTT CO_2e Emissions (kt) [1]	Field Life Scope 1 CO_2e Emissions (kt) [2]	Net Further Refinement, Transportation & Distribution CO_2e Emissions (kt)
High Case (P10)	1,242.36	50.36	**1,192.00**
Mid Case (P50)	883.84	35.72	**848.12**
Low Case (P90)	495.48	20.31	**475.17**

[1] Refer to totals in Table E.6
[2] Refer to totals in Table E.2

End Use of Sold Products

Calculation Methodology

The following equation has been used to calculate the total quantity of scope 3 emissions generated from the end use of sold products (namely, the presumption that all end use Kyla hydrocarbons are eventually combusted):

$$End\ Use\ GHG\ Emissions = Production\ (Oil\ or\ Gas) \times GHG\ Conversion\ Factor$$

Table E.8 lists the GHG conversion factors which have been used to calculate End Use GHG emissions.

Table E.8: End Use GHG Conversion Factors (DESNZ, 2025a)

Kyla Hydrocarbon	Proxy Fuel	GHG Conversion Factors (kg CO_2e of GHG per unit)			
		CO_2	N_2O	CH_4	CO_2e [1]
Oil	'Fuel Oil' (DESNZ, 2025a)	3216.38	5.38720	7.12200	3228.88920
Gas	'Natural Gas (100% mineral blend)' (DESNZ, 2025a)	2,598.26	3.8528	1.19161	2,603.30441

[1] The GWPs used in the calculation of CO_2e are based on the IPCC Fifth Assessment Report (AR5).

Quantification of GHG Emissions

Kyla High Case (P10)

Table E.9: GHG Emissions from Combustion of Kyla Gas and Oil (High Case, P10)

Year	Volume of Gas Produced [1]		Emissions (kt) [2]			
	Mm^3/yr	kt/yr	CO_2	N_2O	CH_4	CO_2e
Combustion of Kyla Gas (Kyla High Case, P10)						
2028	8.12	8.63	22.43	0.03	0.01	22.47
2029	52.86	56.19	145.99	0.22	0.07	146.28
2030	44.17	46.96	122.00	0.18	0.06	122.24
2031	34.96	37.16	96.55	0.14	0.04	96.73
2032	29.68	31.55	81.98	0.12	0.04	82.14
2033	25.82	27.44	71.31	0.11	0.03	71.44
2034	23.45	24.92	64.76	0.10	0.03	64.88
2035	21.65	23.02	59.81	0.09	0.03	59.93
Totals:	**240.71**	**255.88**	**664.83**	**0.99**	**0.30**	**666.12**
Year	**Volume of Oil Produced (kt/yr) [3]**		**GHG Emissions (kt) [2]**			
			CO_2	N_2O	CH_4	CO_2e
Combustion of Kyla Oil (Kyla High Case, P10)						
2028	50.70		163.08	0.27	0.36	163.72
2029	339.03		1,090.43	1.83	2.41	1,094.67
2030	290.56		934.54	1.57	2.07	938.17
2031	232.26		747.04	1.25	1.65	749.95
2032	197.67		635.79	1.06	1.41	638.27
2033	172.58		555.08	0.93	1.23	557.24
2034	157.42		506.33	0.85	1.12	508.30
2035	146.21		470.27	0.79	1.04	472.09
Totals:	**1,586.43**		**5,102.57**	**8.55**	**11.30**	**5,122.42**
	High Case (P10) Totals:		**5,767.40**	**9.53**	**11.60**	**5,788.54**

[1] Gas volumes based on Kyla high case (P10) production profile (refer to Appendix G), with production commencing in September 2028 and cessation of production in December 2035. Gas converted from m^3 to tonnes using a density of 1.066 kg/m^3.

[2] Refer to GHG Conversion Factors in in Table E.8.

[3] Oil volumes based on Kyla high case (P10) production profile (refer to Appendix G), with production commencing in September 2028 and cessation of production in December 2035.

Kyla Mid Case (P50)

Table E.10: GHG Emissions from Combustion of Kyla Gas and Oil (Mid Case, P50)

Year	Volume of Gas Produced [1]		Emissions (kt) [2]			
	Mm^3/yr	kt/yr	CO_2	N_2O	CH_4	CO_2e
Combustion of Kyla Gas (Kyla Mid Case, P50)						
2028	7.33	7.79	20.25	0.03	0.01	20.29
2029	40.35	42.89	111.44	0.17	0.05	111.66
2030	33.15	35.24	91.57	0.14	0.04	91.75
2031	24.83	26.39	68.58	0.10	0.03	68.71
2032	19.56	20.80	54.04	0.08	0.02	54.14
2033	16.14	17.16	44.58	0.07	0.02	44.67
2034	14.31	15.21	39.52	0.06	0.02	39.60
2035	13.28	14.12	36.68	0.05	0.02	36.75
Totals:	**168.96**	**179.60**	**466.66**	**0.69**	**0.21**	**467.56**
Year	**Volume of Oil Produced (kt/yr) [3]**		**Emissions (kt) [2]**			
			CO_2	N_2O	CH_4	CO_2e
Combustion of Kyla Oil (Kyla Mid Case, P50)						
2028	46.69		150.17	0.25	0.33	150.75
2029	263.64		847.96	1.42	1.88	851.26
2030	220.65		709.69	1.19	1.57	712.45
2031	167.72		539.46	0.90	1.19	541.56
2032	132.91		427.50	0.72	0.95	429.17
2033	109.94		353.61	0.59	0.78	354.98
2034	97.63		314.02	0.53	0.70	315.24
2035	90.87		292.29	0.49	0.65	293.42
Totals:	**1,130.06**		**3,634.69**	**6.09**	**8.05**	**3,648.83**
	Mid Case (P50) Totals:		**4,101.35**	**6.78**	**8.26**	**4,116.39**

[1] Gas volumes based on Kyla mid case (P50) production profile (refer to Appendix G), with production commencing in September 2028 and cessation of production in December 2035. Gas converted from m^3 to tonnes using a density of 1.066 kg/m^3.

[2] Refer to GHG Conversion Factors in in Table E.8.

[3] Oil volumes based on Kyla mid case (P50) production profile (refer to Appendix G), with production commencing in September 2028 and cessation of production in December 2035.

Kyla Low Case (P90)

Table E.11: GHG Emissions from Combustion of Kyla Gas and Oil (Low Case, P90)

Year	Volume of Gas Produced [1]		Emissions (kt) [2]			
	Mm^3/yr	kt/yr	CO_2	N_2O	CH_4	CO_2e
Combustion of Kyla Gas (Kyla Low Case, P90)						
2028	2.52	2.67	6.95	0.01	0.00	6.96
2029	15.51	16.49	42.84	0.06	0.02	42.92
2030	14.55	15.47	40.19	0.06	0.02	40.27
2031	13.96	14.84	38.56	0.06	0.02	38.64
2032	13.85	14.72	38.26	0.06	0.02	38.33
2033	13.42	14.27	37.06	0.05	0.02	37.14
2034	13.40	14.24	37.00	0.05	0.02	37.07
2035	13.59	14.44	37.53	0.06	0.02	37.60
Totals:	**100.80**	**107.15**	**278.40**	**0.41**	**0.13**	**278.94**
Year	**Volume of Oil Produced (kt/yr) [3]**		**Emissions (kt) [2]**			
			CO_2	N_2O	CH_4	CO_2e
Combustion of Kyla Oil (Kyla Low Case, P90)						
2028	15.59		50.15	0.08	0.11	50.34
2029	96.50		310.38	0.52	0.69	311.58
2030	90.73		291.82	0.49	0.65	292.95
2031	87.15		280.30	0.47	0.62	281.39
2032	86.60		278.54	0.47	0.62	279.62
2033	84.01		270.20	0.45	0.60	271.25
2034	83.97		270.08	0.45	0.60	271.13
2035	85.14		273.84	0.46	0.61	274.91
Totals:	**629.69**		**2,025.31**	**3.39**	**4.48**	**2,033.19**
	Low Case (P90) Totals:		**2,303.71**	**3.81**	**4.61**	**2,312.13**

[1] Gas volumes based on Kyla low case (P90) production profile (refer to Appendix G), with production commencing in September 2028 and cessation of production in December 2035. Gas converted from m^3 to tonnes using a density of 1.066 kg/m^3.

[2] Refer to GHG Conversion Factors in in Table E.8.

[3] Oil volumes based on Kyla low case (P90) production profile (refer to Appendix G), with production commencing in September 2028 and cessation of production in December 2035.

Total Downstream Scope 3 Emissions

Table E.12 details the total downstream scope 3 emissions which will be generated from the proposed Kyla Development assuming the Triton FPSO continues to operate as normal (i.e. powered by GTGs).

Table E.12: Kyla Development Total Downstream Scope 3 Emissions

Downstream Activities	Total GHG CO_2e Emissions (kt)
Kyla High Case (P10)	
Further Refinement, Transportation and Distribution Emissions	1,242.36
End Use of Sold Products	5,788.54
Total High Case (P10):	**7,030.90**
Kyla Mid Case (P50)	
Further Refinement, Transportation and Distribution Emissions	883.84
End Use of Sold Products	4,116.39
Total Mid Case (P50):	**5,000.23**
Kyla Low Case (P90)	
Further Refinement, Transportation and Distribution Emissions	495.48
End Use of Sold Products	2,312.13
Total Low Case (P90):	**2,807.61**

E.4 Summary of Total GHG Emissions

Table E.13 details the total GHG emissions estimated to be generated as a result of the proposed Kyla Development, based on the highest production case, assuming the Triton FPSO continues to operate as normal (i.e. powered by GTGs).

Table E.13: Kyla Development Total GHG Emissions

Emissions Category	Total GHG CO_2e Emissions (kt)		
	P10 (High)	P50 (Mid)	P90 (Low)
Total Direct GHG Emissions (Scope 1) [1]	50.36	35.72	20.31
Total Indirect Upstream GHG Emissions (Scope 3) [2]	53.19	53.19	53.19
Total Indirect Downstream GHG Emissions (Scope 3) [3]	7,030.90	5,000.23	2,807.61
Grand Total	**7,134.45**	**5,089.14**	**2,881.11**

[1] Refer to Section H.2.1

[2] The total indirect upstream GHG emissions generated are the same for all Kyla production profiles (refer to Section H.3.1).

[3] The total indirect downstream GHG emissions generated depend on the Kyla production profiles as the methodology applies GHG conversion factors to production volumes (refer to Sections H.3.2).

In summary, the P10 case total gross GHG emissions generated over the life of the Kyla Field are estimated to be ca. 7,134.45 kilotonnes of CO_2e, based on the high production case (P10 profile) which represents a highest production emissions profile. It should be noted, however, that there is only a 10% probability that recovered volumes will meet or exceed the P10 case estimate.

For context, the P50 (mid case) scenario, generates total GHG emissions approximately 29% lower than the P10 (high case) estimate, and the P90 (low case) scenario, representing a conservative, lower production outcome, is approximately 60% lower than the P10 (high case) estimate.

In contrast, a 'do-nothing' scenario (e.g. a scenario where the Kyla Development does not proceed) would result in the generation of zero GHG emissions.

Appendix F: Oil Spill Modelling Study

This appendix presents the results of the oil spill modelling study undertaken to support the Kyla Development ES in order to gain an understanding of the behaviour of a potential worst case oil spill scenario in the marine environment originating from a subsea well blowout. The modelling has been completed in line with the OPRED Guidance Notes for Preparing Oil Pollution Emergency Plans for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022).

F.1 OILMAP Spill Modelling Package

This oil spill modelling study has been carried out in RPS ASA's OILMAP (Version 7.7.218.1528) modelling system, which predicts the surface trajectory of spilled oil and includes algorithms for oil spreading, evaporation, emulsification, entrainment, and oil shoreline interaction. The distribution and mass balance of oil with respect to time are predicted for the specific oil spilled. Additional modules are utilised in OILMAP to execute more in-depth modelling processes such as simulating subsurface oil releases and computing probability.

The following modules have been utilised in OILMAP for the Kyla Development oil spill modelling study:

- **OILMAP Deep:** This module is a near-field model used to simulate subsurface releases of oil and gas. OILMAP Deep predicts the near-field plume characteristics and oil droplet size distributions for a specified release.
- **Trajectory and Fates Model:** The trajectory and fates module is a far-field model, for surface and subsurface releases, that predicts the 3D trajectory and fate of oil for instantaneous or continuous release spills.
- **Stochastic Model (RunStoch):** The stochastic module is used for risk assessment and contingency planning. It helps determine the most likely spill paths and the minimum time for oil to reach specific points on monthly, seasonal, or annual basis.

F.1.1 OILMAP Deep

The OILMAP Deep module was developed as an enhanced version of the OILMAP modelling system and is based on published work on plume formation and behaviour as well as droplet formation. The OILMAP Deep model contains two major sub-models, the droplet size distribution model and the plume model.

The droplet size distribution model employs a character diameter calculation (d_{95} hereby referred to as maximum droplet size) and the Rosin Rammler distribution (Yapa et al., 2001) based on the oil properties (primarily the interfacial tension between oil and seawater) and the energy of the release through calculation of the dimensionless Weber number associated with the release. The Weber number is based on the volumetric release rate, the pipe diameter and receiving water density in the numerator, and the oil interfacial tension (IFT) in the denominator. The maximum droplet diameter for a release is related to the Weber number, i.e. a larger Weber number results in larger droplet size. Therefore, lowering the IFT or increasing exit velocity results in a distribution of relatively smaller droplets.

The plume model solves equations for the conservation of water mass, momentum, buoyancy, and gas mass using integral plume theory, following work outlined in McDougall (1978), Spaulding (1982), and Fanneløp and Sjøen (1980). A simplified integral jet theory is employed for the vertical and horizontal motions of the gas-oil plume. The necessary model parameters defining the rates of entrainment and spreading of the jet are obtained from laboratory studies. The plume model calculates the evolution of the blowout plume as it rises and entrains water until it eventually either surfaces or comes into equilibrium with the receiving water. The receiving water is characterized by a site-specific, depth-variable temperature and density profile. These water column properties influence the plume properties since the state of gas is a function of the temperature and pressure. Similarly, temperature and pressure are used to adjust plume bulk density, based on the volume of entrained seawater, to determine the depth at which the plume bulk density approaches the receiving water density. At the point the plume bulk density is equal to that of the receiving water, plume ascension ceases, and the

plume becomes trapped at what is referred to as the termination (plume trap) height. The plume dynamics account for oil and gas buoyancy, gas compression and expansion as a function of depth, hydrate formation, dynamic gas bubble size distribution formulation, gas dissolution, and seawater entrainment and plume spreading processes.

F.1.2 Trajectory and Fates Model

Following OILMAP Deep, the Trajectory and Fates model simulates the droplet rise phase and surfaced oil. The model predicts the transport and weathering of oil from instantaneous or continuous spills. Predictions show the location and concentration of the surface and subsurface oil versus time. The model estimates the temporal variation of the oil's areal coverage, oil thickness, and oil viscosity.

The model also predicts the oil mass balance or the amount of oil on the free surface, in the water column, evaporated, on the shore, and outside the study domain versus time. The fate processes in the model include spreading, evaporation, entrainment or natural dispersion, emulsification and an oil-shoreline interaction:

- **Spreading** is represented using the thick slick portion of Mackay *et al*. (1980, 1982) thick-thin approach.
- **Evaporation** is based on Mackay's analytic formulation parameterized in terms of evaporative exposure (Mackay *et al*., 1980, 1982).
- **Entrainment or Natural Dispersion** is modelled using Delvigne and Sweeney's (1988) formulation which explicitly represents oil injection rates into the water column by droplet size. The entrainment coefficient, as a function of oil viscosity, is based on Delvigne and Hulsen (1994).
- **Emulsification** of the oil, as function of evaporative losses and changes in water content, is based on Mackay et al. (1980, 1982).
- **Oil-Shoreline Interaction** is modelled based on a simplified version of Reed *et al*. (1989) which formulates the problem in terms of a shore type dependent holding capacity and exponential removal rate.

F.1.3 Stochastic Model (RunStoch)

The stochastic model is useful as a contingency planning tool. It is used to determine the range of distances and directions oil spills from a particular site are likely to travel, given the historical wind speed and direction data for the area. The stochastic model performs a large number of single simulations (typically 100 individual trajectory runs) for a given spill site, varying the wind and tidal conditions for each scenario. These trajectories are used to predict probabilities and minimum time that water surface and shoreline areas will be oiled by a release from the given site.

Figure F.1 shows how a simple probability map is created. The example uses four trajectory runs to create a final probability map. Following the same example, Figure F.2 demonstrates how to interpret probability and features of interest (e.g. marine protected areas).

Figure F.1: Diagram to show how stochastic probability maps are made

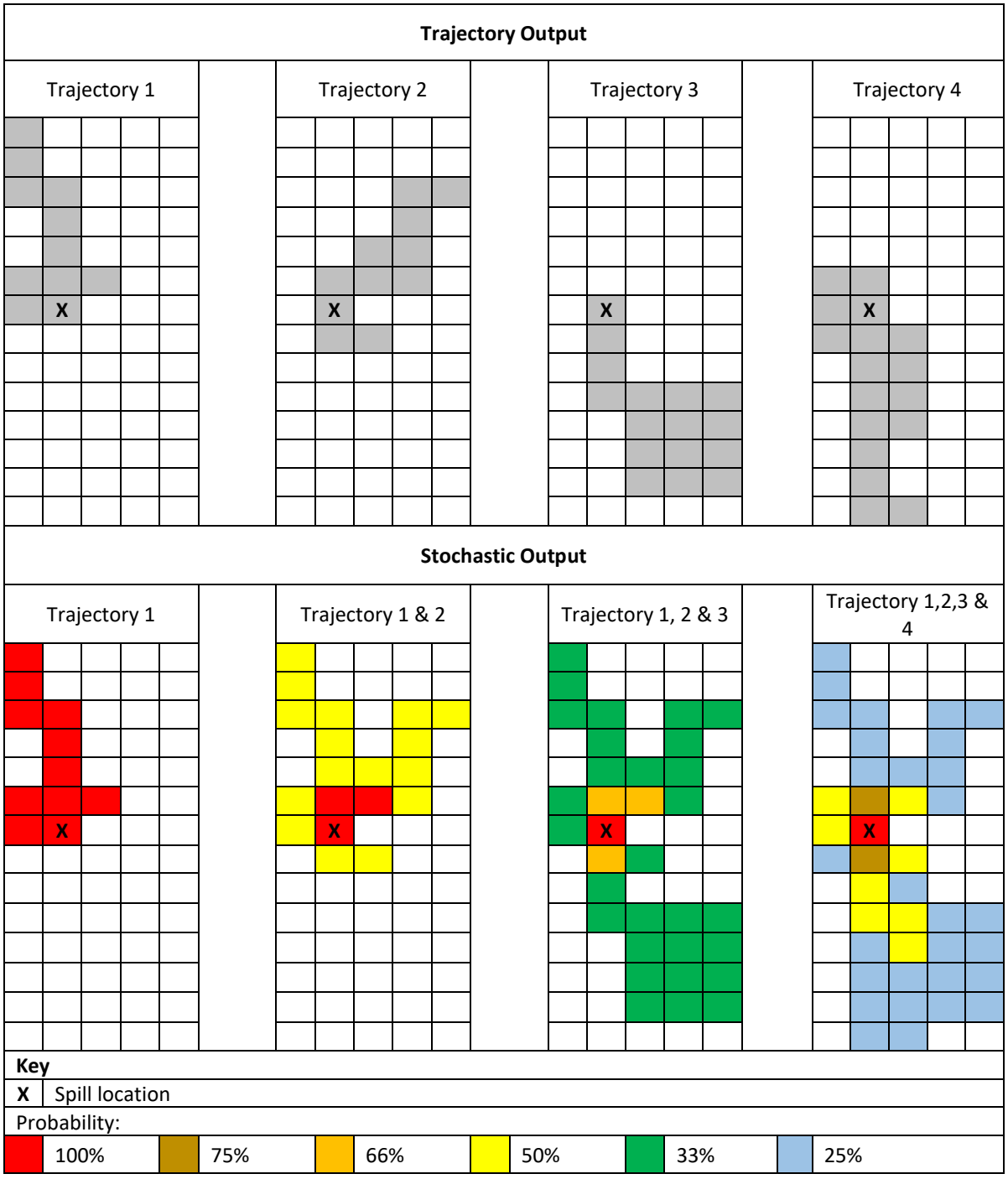
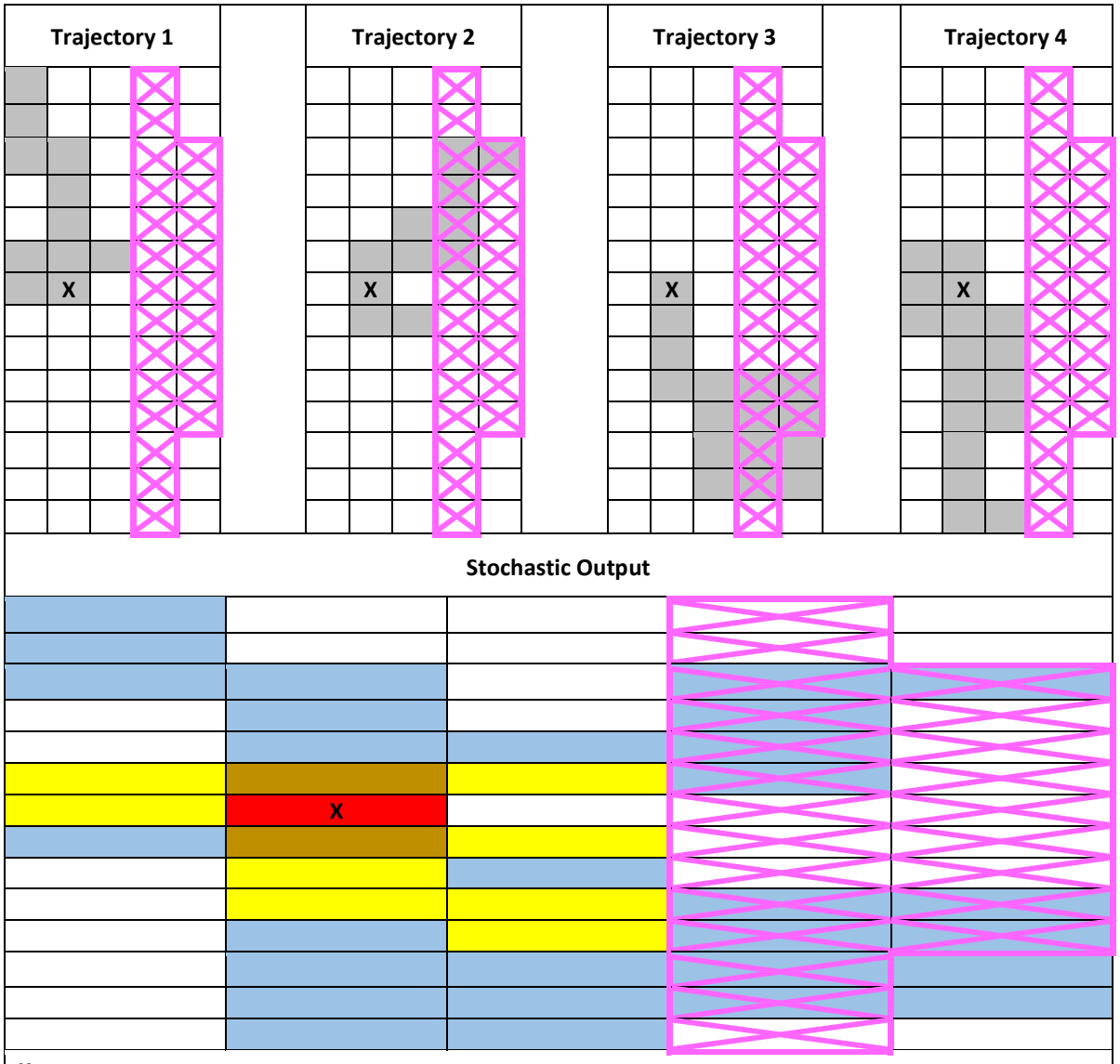


Figure F.2: Interpretation of Probability Mapping (Probability Grid vs Context Driven)



Key	
X	Spill location
	Marine Protected Area
Gridded Probability Output:	
100%	75%	66%	50%	33%	25%

Interpretation of Probability

A grid is over laid onto the trajectory runs to produce the gridded probability output. The grid 'cell size' is important in determining the resolution of the results.

A typical grid cell size for a blowout scenario is 1 x 1 km.

Overlaying features (e.g. Marine Protected Areas) onto a probability map can be misleading when interpreting results. In the example above, the gridded probability suggests that there is a 25 % probability of the Marine Protected Area being hit by oil. Whereas, a context driven approach that counts the number of trajectory runs that enter the Marine Protected Area produces a probability of 50 % (i.e. two trajectory simulations out of four enter the Marine Protected Area).

Therefore, to avoid underestimating probability a context driven approach is used when reporting results.

F.2 Modelled Scenario

F.2.1 Worst Case Spill Scenario

The following worst case spill scenario has been modelled for the Kyla Development:

- Subsurface blowout release from the Kyla Development well with a cumulative release of 5,458,587.90 barrels (bbl) (867,860.89 cubic metre (m^3)) of 37.8°API crude, released over a period of 132 days.

F.2.2 Summary of Model Input Parameters

The model input parameters for the Kyla Development subsea blowout scenario are detailed in Table F.1.

Table F.1: Model Input Parameters for a Subsurface Blowout in the Kyla Development

Scenario 1: Well Loss Parameters			
Loss from Well / FPSO / Rig (please specify)	Kyla Development Subsea Well Blowout	**Instantaneous Loss?**	No
Worst case volume	5,458,587.90 bbl (867,860.89 m^3)	**Will the well self-kill? If yes, when**	No, it is assumed a relief well would be required.
Flow rate	Declining flow rate - starting at 49,856.60 bbl (7,927.20 m^3) / day on day 1, declining to 32,853.50 bbl (5,223.71 m^3) / day on day 132 (refer to Section F.6.4)		
Justification for predicted worst case volume	This represents the anticipated worst case blowout scenario for the Kyla Development in terms of both the volume of crude which would be released and the duration of the spill (i.e. it assumes the flow can only be stemmed by drilling a relief well which would take a total of 132 days to drill).		
Location			
Spill Source point Latitude (N/S)	56° 52′ 58.7283″ N;	**Spill source point Longitude (E/W)**	01° 13′ 45.1198″ E
Installation / Facility Name	Proposed Kyla Development Well	**Quad / Block**	29/02
Hydrocarbon Properties			
Hydrocarbon name	Crude		
Assay available	No	**Was an analogue used for spill modelling?**	Yes –the Chayvo #6 Crude assay was amended to match the expected Kyla Crude properties.

	Name	**ITOPF Category**	**Density**	**API**	**Viscosity at temp**	**Pour Point (°C)**	**Wax Content (%)**	**Asphaltene Content (%)**
Analogue	Amended Chayvo #6 Crude Analogue (refer to Section F.6.3)	Group 2	0.8365 g/cm^3 @ 15°C	37.8°	19cP @ 0°C; 4cP @ 15°C	3	7	0.15

Metocean Parameters				
Sea surface temperature	Winter (Dec – Feb)	7°C	Summer (June – Aug)	14°C
	Spring (Mar – May)	9°C	Autumn (Sep – Nov)	10°C
Wind data	Data period	2019 – 2023		
	Data reference	European Centre for Medium-Range Weather Forecasts (ECMWF) - Reanalysis v5 (ERA5)		
Current data	Data period	2019 – 2023		
	Data reference	HYCOM (HYbrid Coordinate Ocean Model) general ocean circulation model and HYDROMAP hydrodynamic model		

Modelled Release Parameters			
Surface or Subsurface	Subsurface	**Depth**	90 m
Release duration	132 Days	**Instantaneous?**	No
Persistence duration	10 Days	**Release rate**	Declining flow rate - starting at 49,856.60 bbl (7,927.20 m^3) / day on day 1, declining to 32,853.50 bbl (5,223.71 m^3) / day on day 132 (refer to Section F.6.4)
Total simulation time	142 Days	**Total cumulative release**	5,458,587.90 bbl (867,860.89 m^3)

Subsea Release Parameters (OILMAP Deep Blowout Model)	Gas to Oil Ratio (GOR)	128.2 m^3/m^3
	Salinity and Temperature Profile	Refer to Section F.6.1.
	Gas Viscosity	0.0190 Centipoise (cP)
	Gas Diffusivity	0.0000000011 m^2/s
	Diameter of Release Hole	0.2204974 m
	Oil Temperature	83.90 °C
	Particle Size / Velocity Distribution Method	Model calculated with 6 droplet size bins
No. of Runs	100 simulation runs per season	

Stochastic Parameters		
Probability grid (Grid Cell Size)	Fixed Cell Size: Cell Size (X and Y axis) = 1,000 metres (m) Cell Size (Z axis) = 500 m	
Distribution of Mass On Grid Cells	Fixed Mass (mass of spillet is placed only in the grid cell that intersects with the centre of the spillet, without any spreading). Mass is not distributed to any other grid cells.	
Minimum Thresholds	Surface Thickness:	0.0003 millimetres (mm)
	Shoreline Thickness:	0.001 mm
	Water Column Concentration:	1.0 parts per billion (ppb)

Oil Spill Modelling Software			
Name of software	OILMAP	**Version**	7.7.218.1528

F.2.3 Reporting Thresholds

Probability and Minimum Time

Table F.2 outlines the minimum oiling thresholds used for this study to determine the probability and minimum time for oiling.

Table F.2: Minimum Oiling Thresholds used for Probability and Minimum Time Reporting

Category	Threshold	Justification
Surface	Minimum Thickness of 0.3 micrometres (µm)	The OPRED Guidance Notes for Preparing OPEPs for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022) states that model results must be displayed to an oil thickness of 0.3 µm.
Water Column	Minimum Concentration of 1.0 ppb (total oil)	Screening threshold for potential effects on sensitive organisms & socio-economic activity (e.g. seafood production) (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, *et al*. 2012).
Shoreline	Minimum Thickness of 1.0 µm	This threshold has been selected for potential effects on socio-economic resource uses, as this amount of oil may conservatively trigger the need for shoreline clean-up on amenity beaches. And impact shoreline recreation and tourism (French-McCay, *et al*. 2011 and French-McCay, *et al*. 2012). Shoreline oiling at this threshold may appear as a coat, patches or scattered tar.

Surface Oiling Severity

The surface oil thickness key in Table F.3 is derived from the Bonn Oil Appearance Code (BOAC). Mapping surface oil thickness by the BOAC will help determine surface oiling severity in the spatial context.

Table F.3: The Bonn Agreement Oil Appearance Code

Code	Description - Appearance	Layer Thickness Interval (µm)	Litres per km^2	Colour
1	Sheen (silvery/grey)	0.04 to 0.30 Note 1	40 – 300	
2	Rainbow	0.30 to 5.0	300 – 5000	
3	Metallic	5.0 to 50	5000 – 50,000	
4	Discontinuous True Oil Colour	50 to 200	50,000 – 200,000	
5	Continuous True Oil Colour	More than 200	More than 200,000	

Note 1: The Oilmap outputs are modelled to a minimum of 0.30 µm as per the OPRED Guidance Notes for Preparing OPEPs for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022).

Water Column Oiling Severity

Table F.4 details four different thresholds for water column oiling concentrations and the effect on marine fauna. The different thresholds are derived from various research papers and will help determine sub surface oiling severity in the spatial context.

Table F.4: Water Column Oil Concentration Thresholds

Minimum Threshold for Water Column Oil Concentration (ppb)	Justification	Colour
1	Screening threshold for potential effects on sensitive organisms & socio-economic activity (e.g. seafood production) (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, et al. 2012).	
70.5	Smit *et al*. (2009) calculated an EC_5 for growth, reproduction and survival of marine organisms of 70.5 ppb THC based on laboratory experiments performed at IRIS (Norway). The dataset included organisms representing five different phyla (fish, crustaceans, polychaetes, echinoderms and molluscs). The 70.5 ppb figure is the OSPAR recommended predicted no-effect concentration (OSPAR, 2014).	

Shoreline Oiling Severity

Table F.5 details three different thresholds for shoreline oiling concentrations that represent light oiling, moderate oiling and heavy oiling. The shoreline oiling classifications are derived from the International Tanker Owners Pollution Federation Limited (ITOPF) Technical Information Paper No.6 'Recognition of oil on shorelines (ITOPF, 2014). The shoreline oiling classifications will help determine shoreline oiling severity in the spatial context.

Table F.5: Shoreline Oil Thickness Thresholds

Shoreline Oiling Classification (ITOPF, 2014)	Thickness Threshold (mm)	Concentration	Colour
Light Oiling	0.001 - <1	0.001 – 1 litres / m^2	
Moderate Oiling	1 – 10	1 – 10 litres / m^2	
Heavy Oiling	>10	>10 litres / m^2	

F.3 Stochastic Modelling Results

F.3.1 Summary of Results

Table F.6 summarises the stochastic results for a worst case subsea well blowout associated with the Kyla Development well across all seasons. The results in Table F.6 report the minimum arrival time and probability of oil to reach land and the territorial waters of nearby countries.

Table F.6: Summary of Stochastic Modelling Results

Scenario 1: Kyla Development Subsea Well Blowout					
Spill Scenario / Descriptor: 5,458,587.90 bbl (867,860.89 m^3) of Crude (37.8 °API) released over 132 days					
Season		Winter (December – February)	Spring (March – May)	Summer (June – August)	Autumn (September – November)
Median Crossing [Note 1]					
Identified Median Line	**Surface Oil: Probability and Shortest Time to Reach (Minimum Thickness of 0.3 µm)**				
Netherlands	*Maximum Probability*	41 %	2 %	1 %	17 %
	Shortest Arrival Time	915 hrs	3,262 hrs	3,087 hrs	1,639 hrs
Germany	*Maximum Probability*	56 %	3 %	1 %	28 %
	Shortest Arrival Time	773 hrs	2,660 hrs	2,460 hrs	1,490 hrs
Denmark	*Maximum Probability*	83 %	20 %	17 %	83 %
	Shortest Arrival Time	379 hrs	761 hrs	890 hrs	683 hrs
Norway	*Maximum Probability*	100 %	100 %	100 %	100 %
	Shortest Arrival Time	78 hrs	134 hrs	190 hrs	103 hrs
Sweden	*Maximum Probability*	54 %	N/A	6 %	69 %
	Shortest Arrival Time	588 hrs	N/A	1,715 hrs	947 hrs
Identified Median Line	**Subsurface Oil: Probability and Shortest Time to Reach (Minimum Water Column Concentration 1.0 ppb)**				
Netherlands	*Maximum Probability*	53 %	2 %	5 %	68 %

	Shortest Arrival Time	835 hrs	3,121 hrs	2,698 hrs	1,144 hrs
Germany	*Maximum Probability*	78 %	12 %	6 %	72 %
	Shortest Arrival Time	540 hrs	2,580 hrs	2,547 hrs	1,147 hrs
Denmark	*Maximum Probability*	91 %	58 %	79 %	100 %
	Shortest Arrival Time	363 hrs	754 hrs	871 hrs	688 hrs
Norway	*Maximum Probability*	100 %	100 %	100 %	100 %
	Shortest Arrival Time	74 hrs	124 hrs	179 hrs	93 hrs
Sweden	*Maximum Probability*	74 %	20 %	54 %	100 %
	Shortest Arrival Time	582 hrs	2,326 hrs	1,545 hrs	907 hrs
Landfall [Note 1]					
Predicted Locations	**Shoreline Oil: Probability and Shortest Time to Reach (Minimum Thickness of 1.0 µm)**				
Germany	*Maximum Probability*	3 %	N/A	N/A	2 %
	Shortest Arrival Time	1,351 hrs	N/A	N/A	2,000 hrs
Denmark	*Maximum Probability*	57 %	3 %	2 %	75 %
	Shortest Arrival Time	818 hrs	2,423 hrs	1,848 hrs	1,070 hrs
Norway	*Maximum Probability*	27 %	2 %	11 %	36 %
	Shortest Arrival Time	762 hrs	2,311 hrs	1,550 hrs	1,136 hrs
Sweden	*Maximum Probability*	22 %	N/A	2 %	40 %
	Shortest Arrival Time	643 hrs	N/A	3,344 hrs	1,060 hrs
UK Counties					
Shetland Isles	*Maximum Probability*	5 %	12 %	3 %	9 %

	Shortest Arrival Time	2,224 hrs	1,484 hrs	2,176 hrs	955 hrs
Orkney	*Maximum Probability*	8 %	7 %	2 %	5 %
	Shortest Arrival Time	1,904 hrs	1,219 hrs	2,083 hrs	1,348 hrs
Caithness	*Maximum Probability*	3 %	2 %	3 %	N/A
	Shortest Arrival Time	1,844 hrs	1,617 hrs	2,147 hrs	N/A
Sutherland	*Maximum Probability*	1 %	2 %	N/A	N/A
	Shortest Arrival Time	2,529 hrs	1,981 hrs	N/A	N/A
Ross & Cromarty	*Maximum Probability*	1 %	2%	N/A	N/A
	Shortest Arrival Time	2,671 hrs	2,676 hrs	N/A	N/A
Nairn	*Maximum Probability*	1 %	N/A	N/A	N/A
	Shortest Arrival Time	2,522 hrs	N/A	N/A	N/A
Moray	*Maximum Probability*	3 %	5 %	2 %	N/A
	Shortest Arrival Time	1,957 hrs	1,674 hrs	2,904 hrs	N/A
Banffshire	*Maximum Probability*	5 %	3 %	4 %	N/A
	Shortest Arrival Time	2,013 hrs	1,284 hrs	1,998 hrs	N/A
Aberdeenshire	*Maximum Probability*	34 %	39 %	7 %	3 %
	Shortest Arrival Time	1,260 hrs	637 hrs	1,095 hrs	764 hrs
City of Aberdeen	*Maximum Probability*	28 %	32 %	4 %	7 %
	Shortest Arrival Time	1,713 hrs	659 hrs	1,221 hrs	796 hrs
Kincardineshire	*Maximum Probability*	33 %	32 %	5 %	3 %
	Shortest Arrival Time	1,539 hrs	666 hrs	561 hrs	710 hrs

Angus	*Maximum Probability*	29 %	28 %	3 %	2 %
	Shortest Arrival Time	1,864 hrs	920 hrs	1,764 hrs	711 hrs
City of Dundee	*Maximum Probability*	12 %	12 %	2 %	N/A
	Shortest Arrival Time	2,178 hrs	963 hrs	2,175 hrs	N/A
Perth and Kinross	*Maximum Probability*	1 %	3 %	N/A	N/A
	Shortest Arrival Time	3,046 hrs	1,962 hrs	N/A	N/A
Fife	*Maximum Probability*	22 %	33 %	2 %	2 %
	Shortest Arrival Time	1,948 hrs	985 hrs	1,734 hrs	1,392 hrs
City of Edinburgh	*Maximum Probability*	1 %	2 %	1 %	N/A
	Shortest Arrival Time	3,198 hrs	1,767 hrs	2,808 hrs	N/A
East Lothian	*Maximum Probability*	13 %	12 %	2 %	N/A
	Shortest Arrival Time	2,015 hrs	950 hrs	2,713 hrs	N/A
Berwickshire	*Maximum Probability*	10 %	10 %	5 %	N/A
	Shortest Arrival Time	1,997 hrs	1,281 hrs	2,703 hrs	N/A
Northumberland	*Maximum Probability*	6 %	7 %	3 %	N/A
	Shortest Arrival Time	2,320 hrs	1,520 hrs	2,715 hrs	N/A
Tyne & Wear	*Maximum Probability*	2 %	3 %	2 %	N/A
	Shortest Arrival Time	2,989 hrs	1,932 hrs	2,733 hrs	N/A
Durham	*Maximum Probability*	N/A	2 %	1 %	N/A
	Shortest Arrival Time	N/A	2,048 hrs	2,824 hrs	N/A
North Yorkshire	*Maximum Probability*	N/A	2 %	N/A	N/A

	Shortest Arrival Time	N/A	2,048 hrs	N/A	N/A
East Riding of Yorks	*Maximum Probability*	N/A	1 %	N/A	N/A
	Shortest Arrival Time	N/A	2,890 hrs	N/A	N/A
Worst Case Trajectory Simulations Identified from Stochastic Results					
Greatest Volume of Oil Beached (in any one location)	*Trajectory Run No. (out of 100)*	33	52	81	34
	m^3	12,030.36	2,632.33	611.72	7,172.86
	bbl	75,662.67	16,555.53	3,847.28	45,112.32
	Tonnes	10,225.81	2,237.48	519.96	6,096.93
	Sim Start Date	03/12/2019	19/03/2021	05/08/2023	08/11/2019
	Sim Start Time	00:00	15:00	23:00	09:00

Note 1: Shortest arrival time and maximum probability values are not necessarily linked to the same run. The results represent a worst-case scenario for each feature based on the analysis of all model runs.

F.3.2 Stochastic Maps

The stochastic results for the Kyla Development worst case subsea well blowout scenario were calculated from a total of 400 trajectory runs (100 simulations per season). The well blowout scenario involves the release of 5,458,587.90 bbl (867,860.89 m^3) of Crude (37.8 °API) over a 132-day period. The model is simulated for an additional 10 days following cessation of the blowout.

The stochastic model analysis used a 1 kilometres (km) x 1 km grid cell size. Therefore, the mapped stochastic output is shown at a 1 square kilometre (km^2) resolution. The following maps are presented using the WGS84 coordinate system:

Sea Surface

- **Figure F.3** - Probability of oil reaching surface cells.
- **Figure F.4** - Minimum arrival time of oil to surface cells.
- **Figure F.5** - Maximum surface oil thickness.

Water Column

- **Figure F.6** - Probability that a water column cell could be impacted.
- **Figure F.7** - Minimum arrival time of oil to water column cells.
- **Figure F.8** - Maximum total water column oil concentration.

Shoreline

- **Figure F.9** - Probability that a shoreline cell could be impacted.
- **Figure F.10** - Minimum arrival time of oil to shoreline cells.
- **Figure F.11** - Maximum shoreline oil thickness.

In accordance with the OPRED Guidance Notes for Preparing OPEPs for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022), the stochastic map outputs have not displayed surface and subsurface oiling probabilities <10 %.

Figure F.3: Probability of Oil Reaching Surface Cells

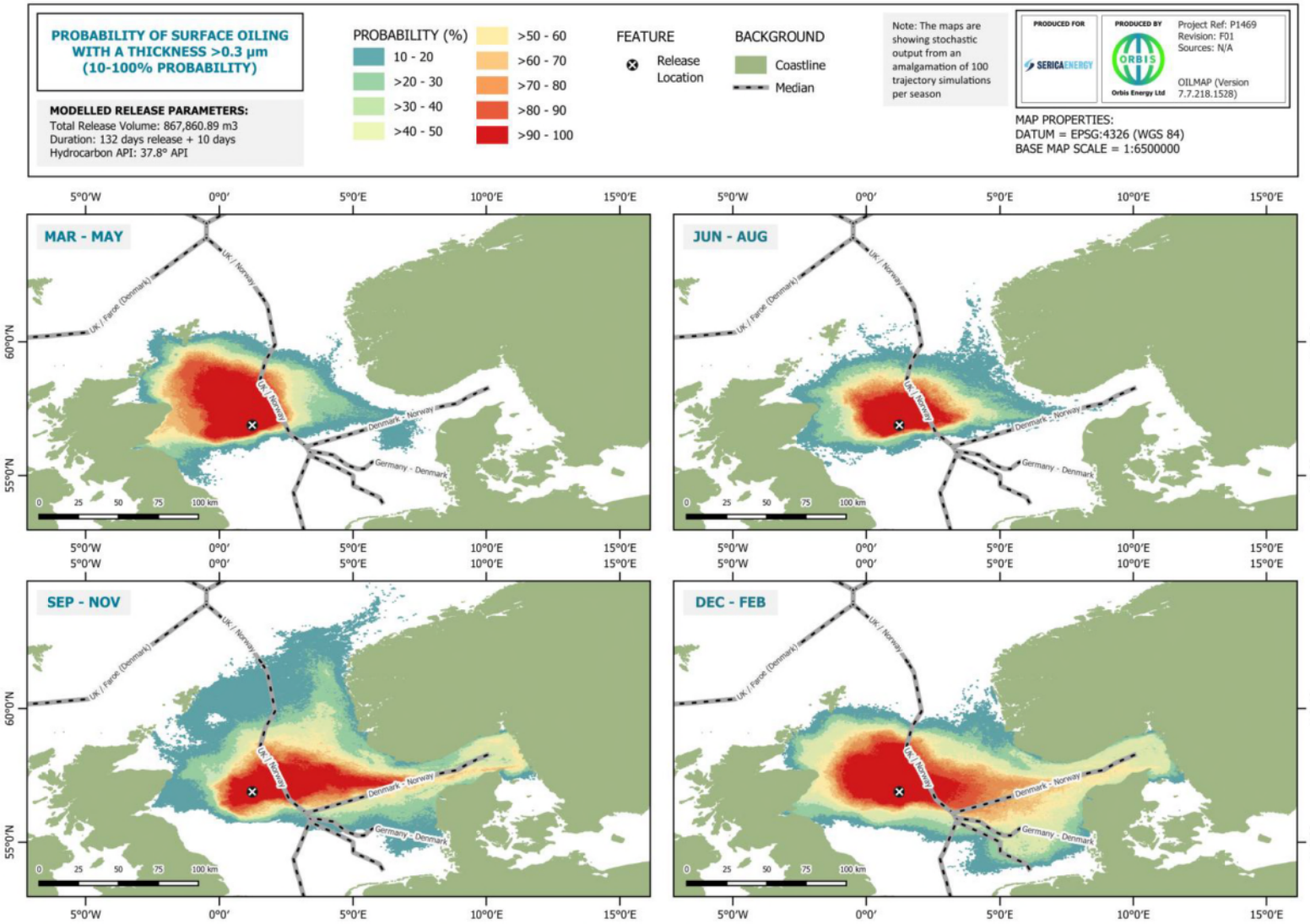


Figure F.4: Minimum Arrival Time of Oil to Surface Cells

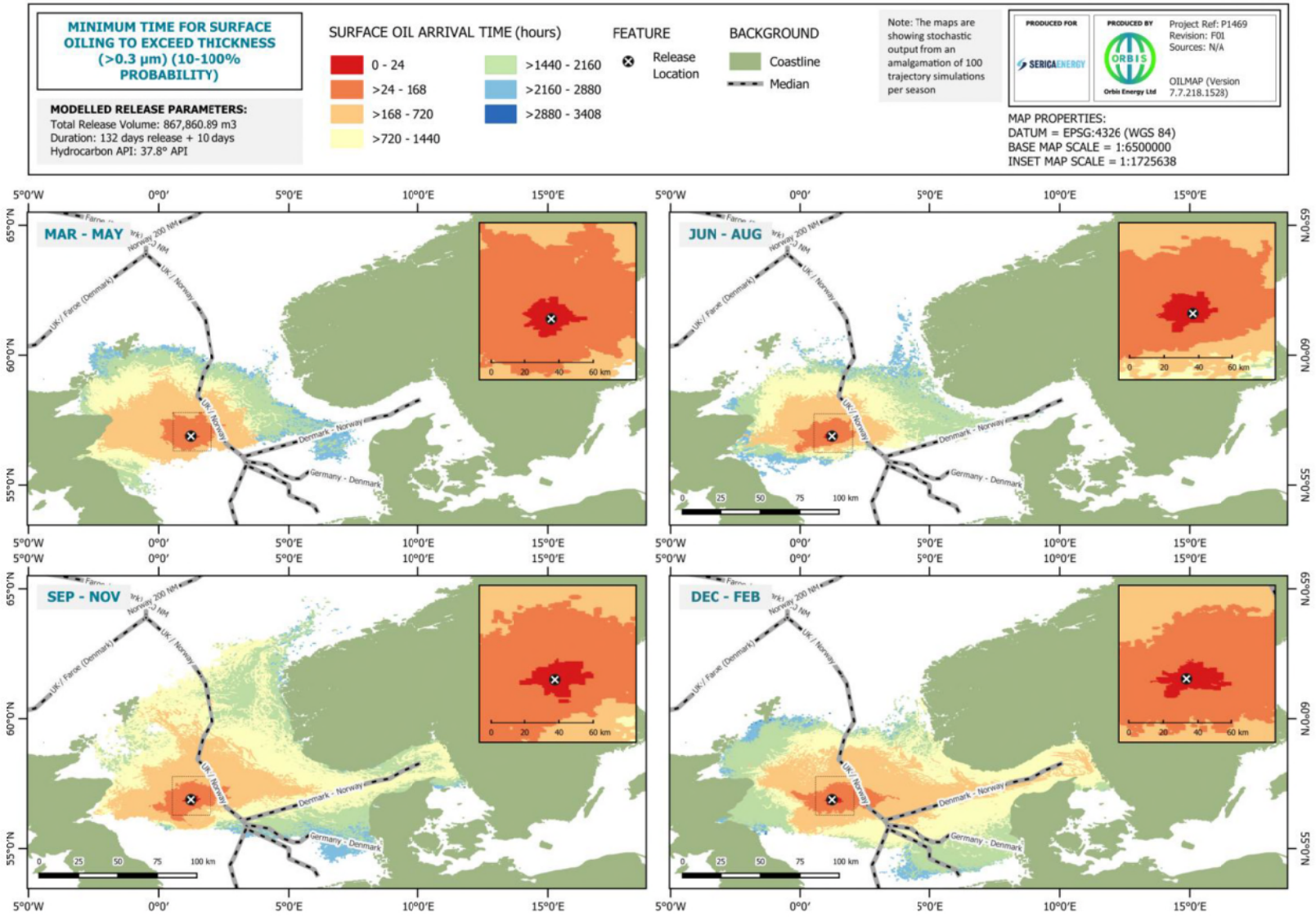


Figure F.5: Maximum Surface Oil Thickness (Bonn Code)

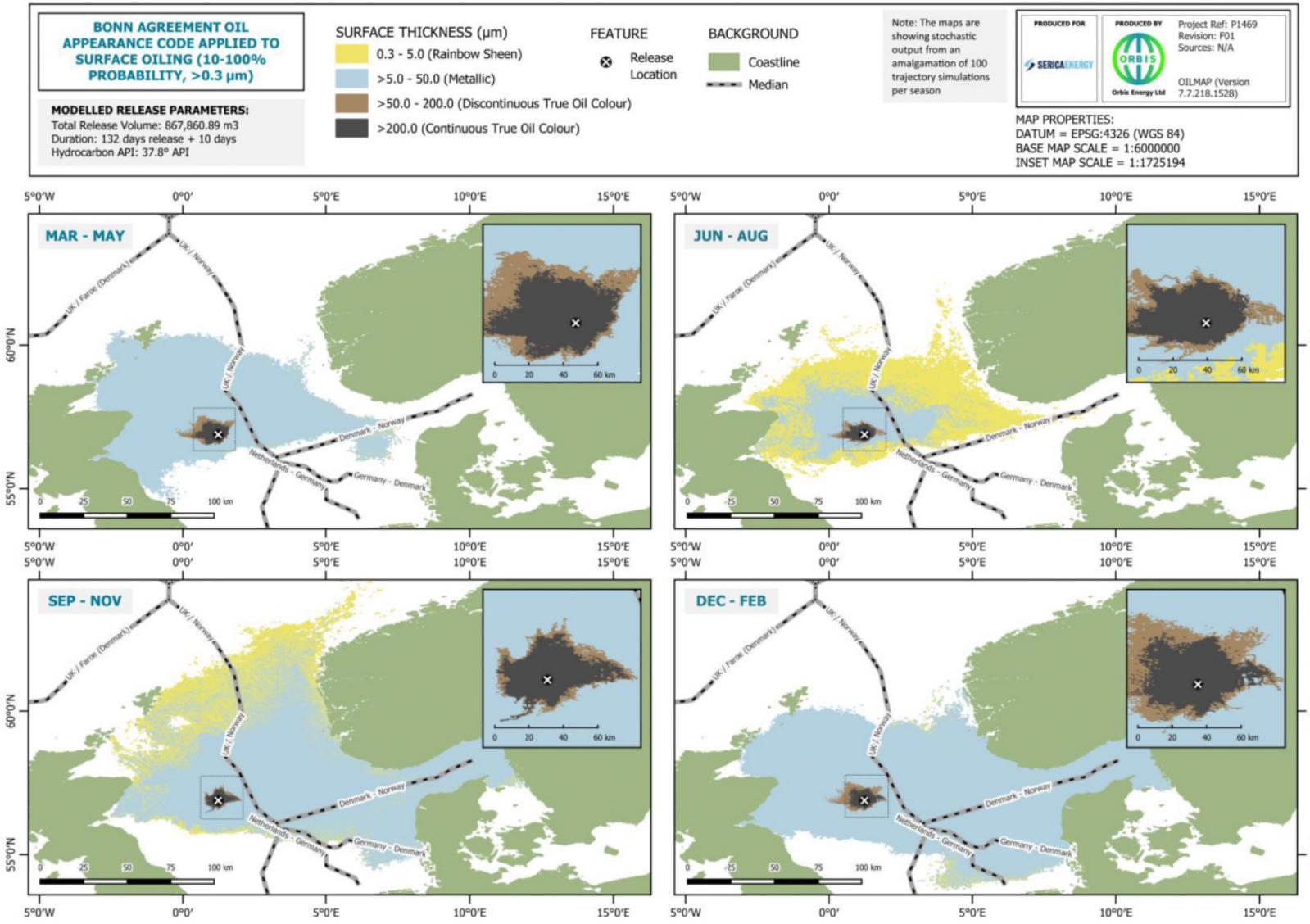


Figure F.6: Probability of Water Column Cells Impacted

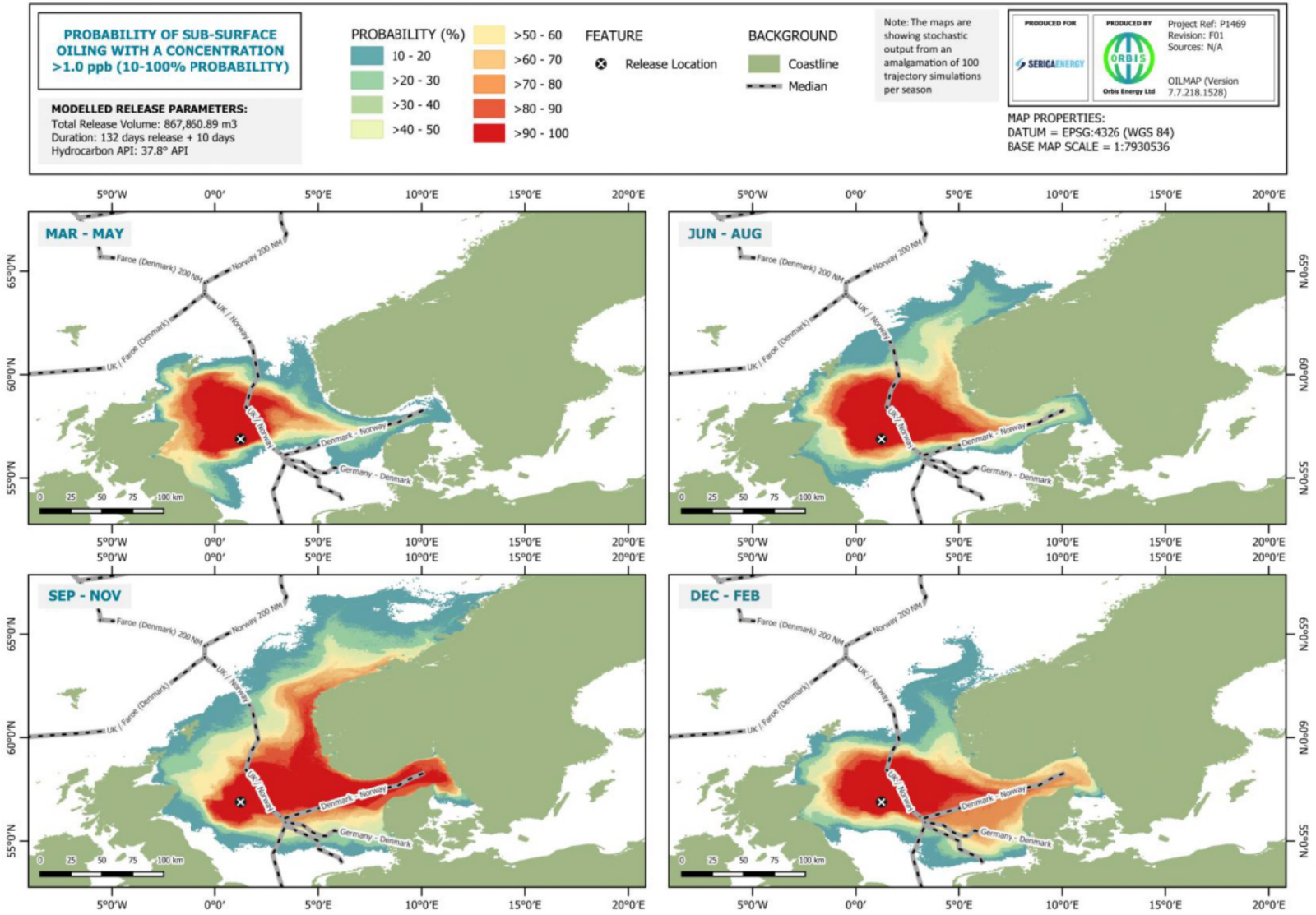


Figure F.7: Minimum Arrival Time of Oil to Water Column Cells

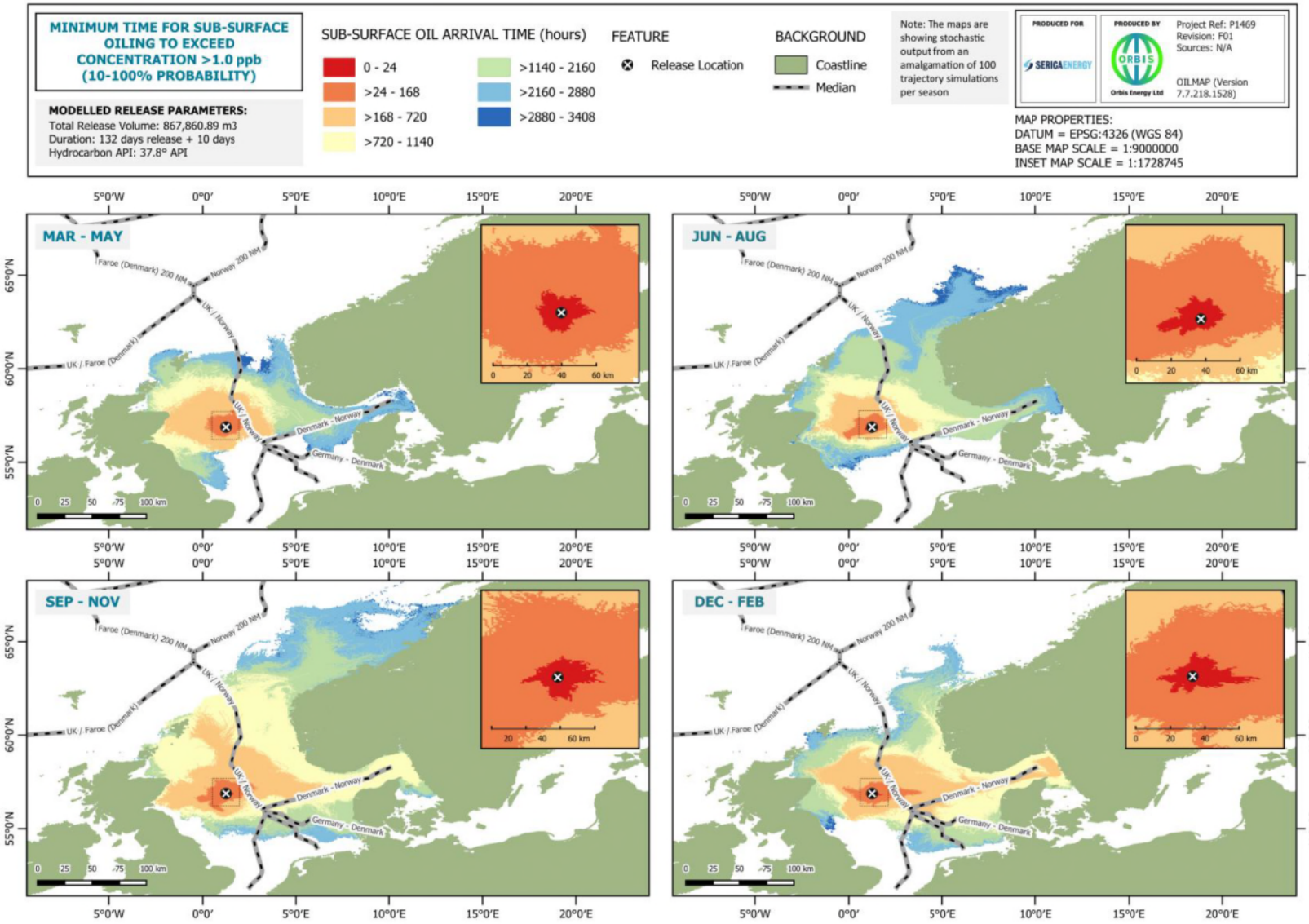


Figure F.8: Maximum Total Water Column Oil Concentrations

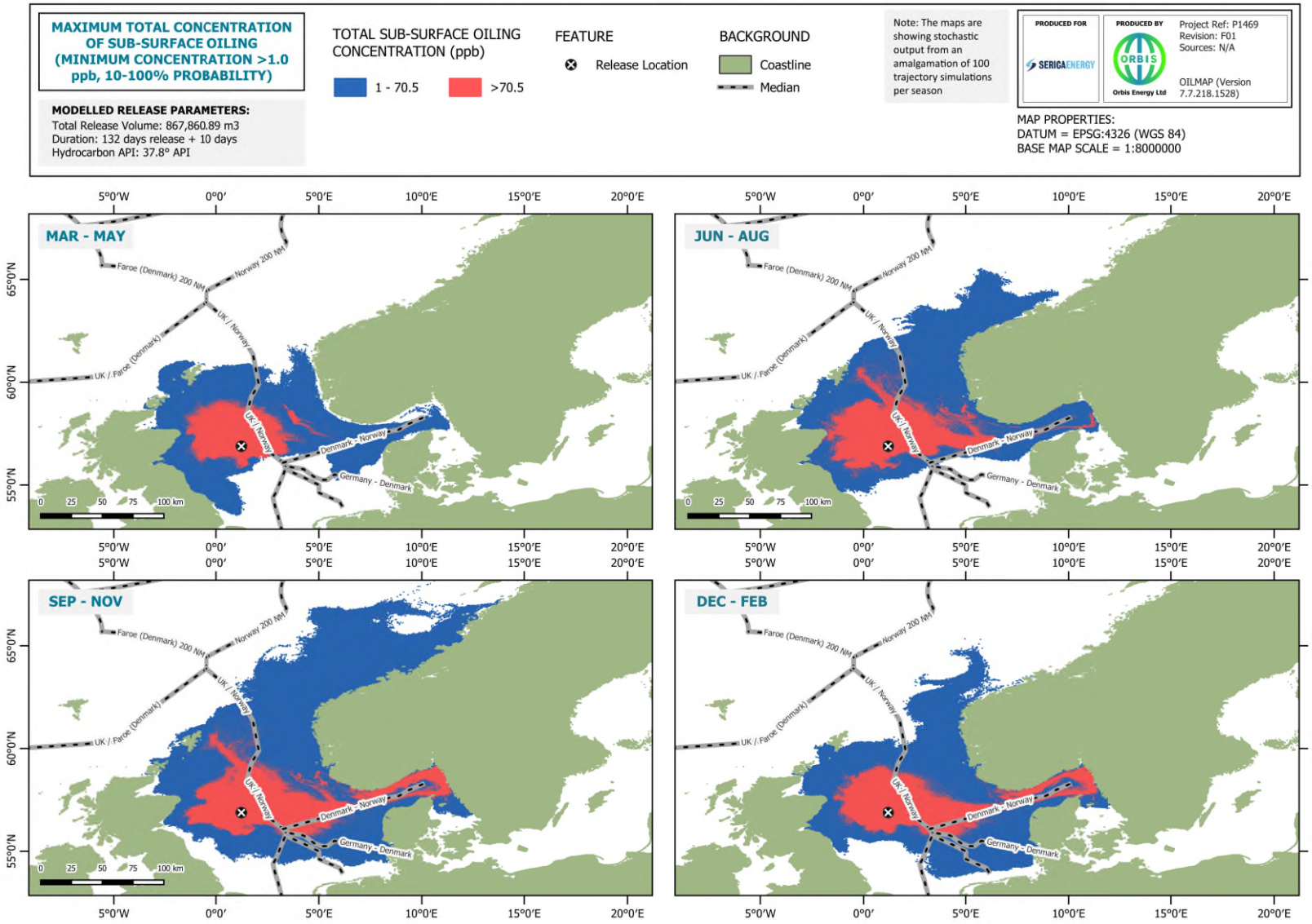


Figure F.9: Probability of Shoreline Oiling

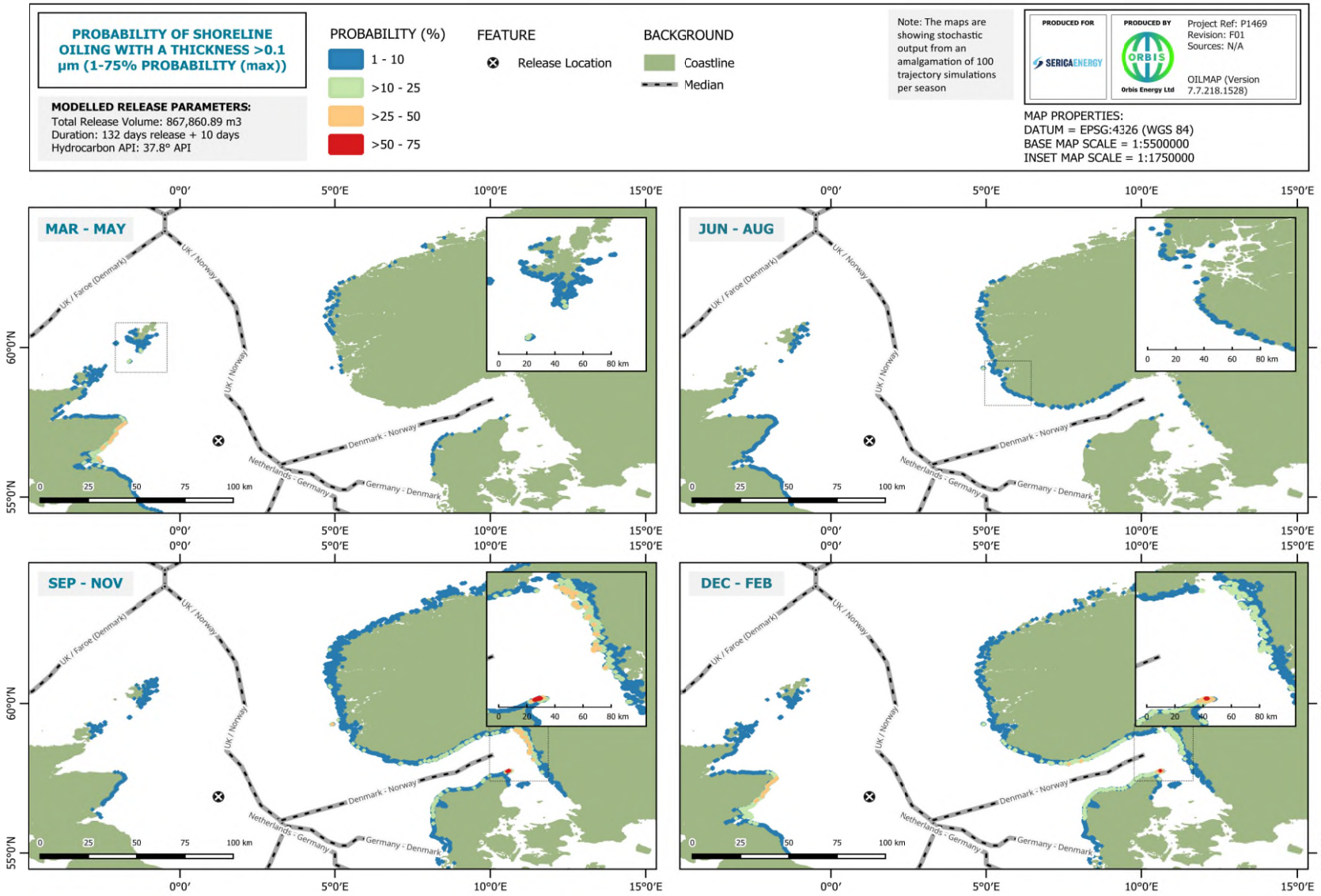


Figure F.10: Minimum Arrival Time of Oil to Shoreline Cells

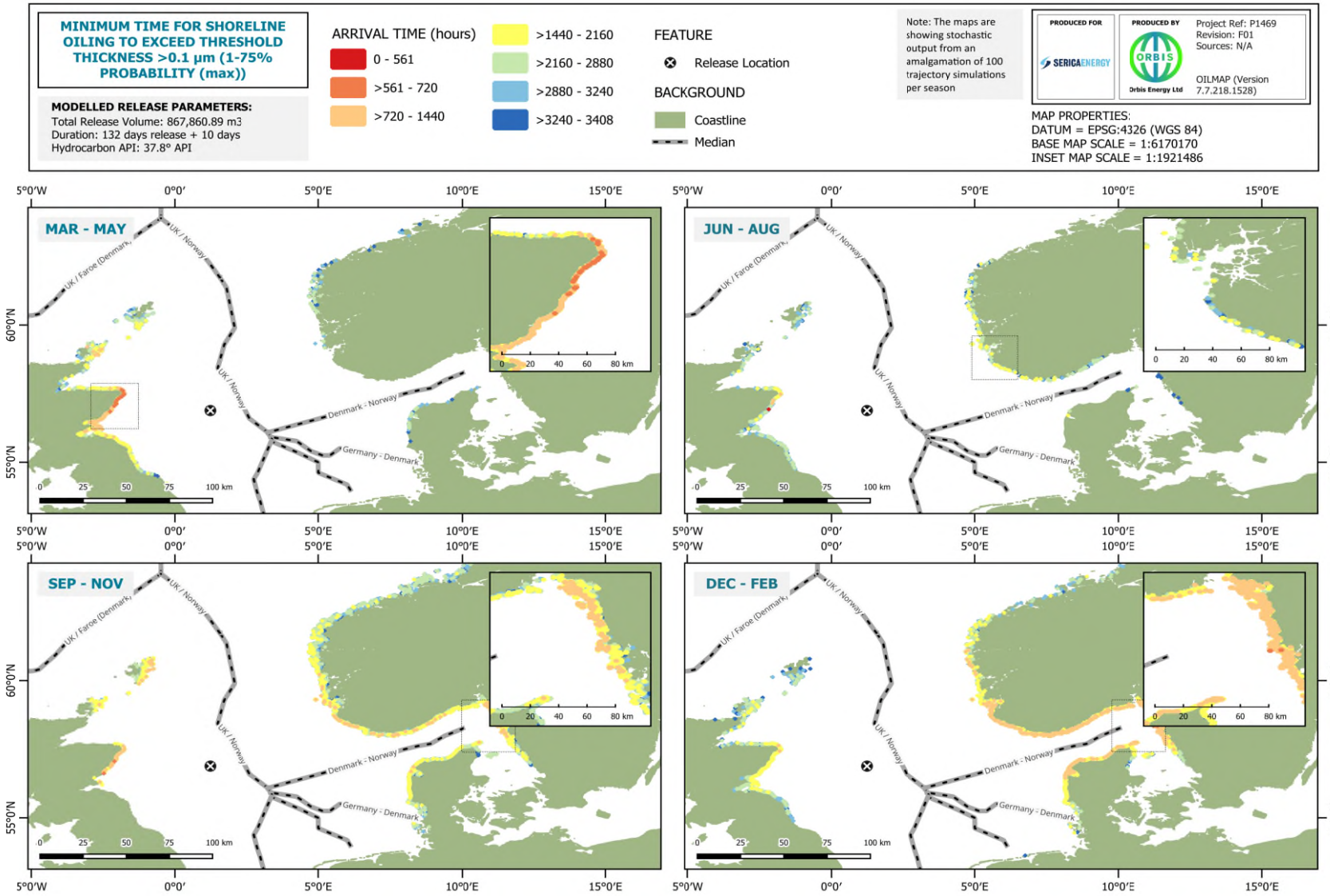
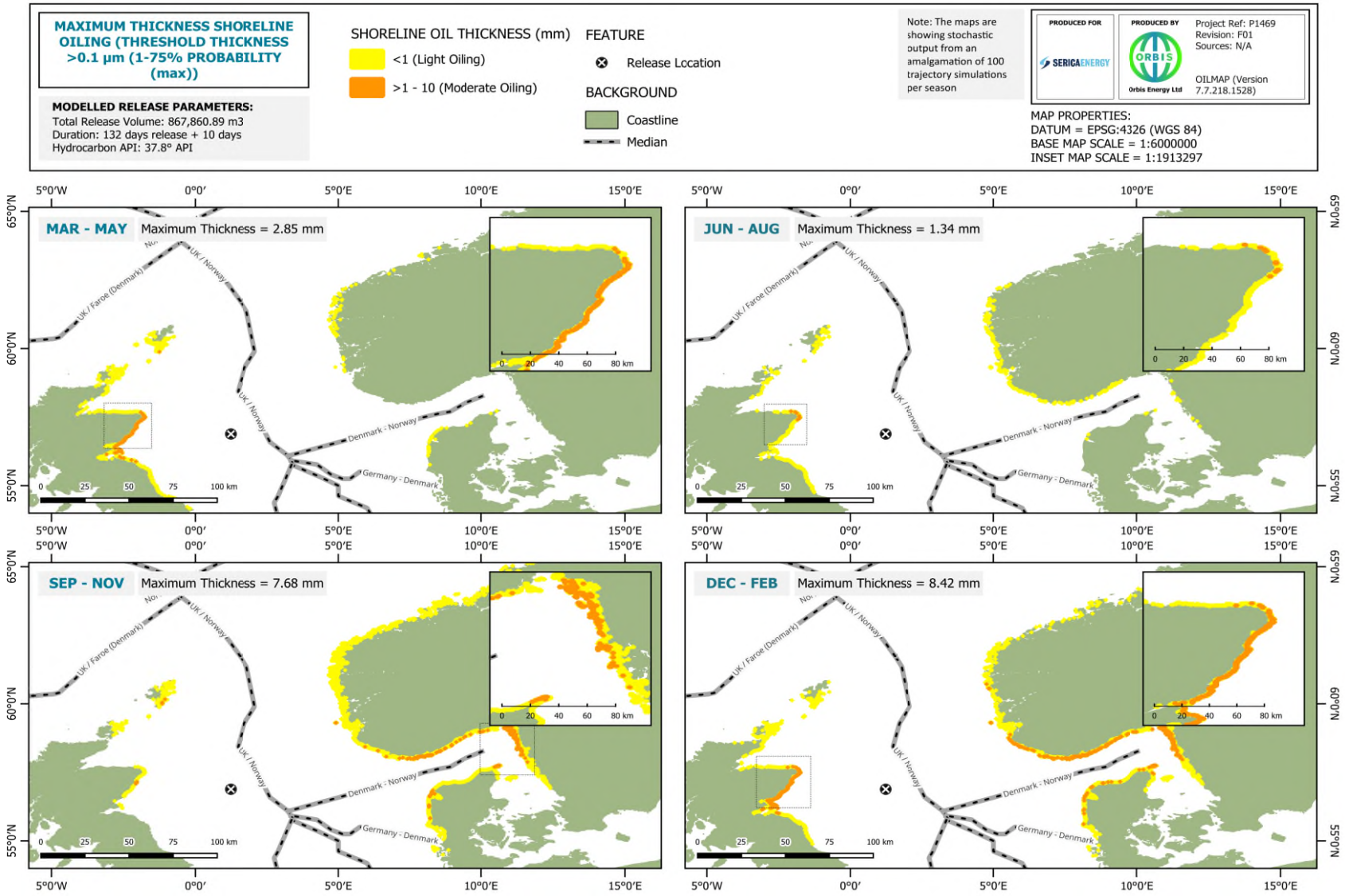


Figure F.11: Maximum Shoreline Oiling Thickness



F.3.3 Protected Areas at Risk

Stochastic Analysis for Protected Areas at Risk

Table F.7 lists the protected areas at risk from oiling. The worst-case probability, minimum time and severity of oiling is reported for surface, shoreline and subsurface oil across all seasons.

Table F.7: Protected Areas at Risk from Surface, Shoreline and Subsurface Oiling [Note 1]

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Special Protected Areas (SPA) with Marine Components									
Auskerry SPA	14 %	1,349 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	24 %	1,353 hrs	Below OSPAR PNEC (<70.5 ppb)
Bluemull and Colgrave Sounds SPA	8 %	1,377 hrs	Bonn Code: 3 Metallic	3 %	1,398 hrs	Light Oiling (0.001 – 1 litres / m^2)	18 %	1,228 hrs	Below OSPAR PNEC (<70.5 ppb)
Buchan Ness to Collieston Coast SPA	68 %	634 hrs	Bonn Code: 3 Metallic	39 %	647 hrs	Moderate Oiling (1 – 10 litres / m^2)	61 %	653 hrs	Above OSPAR PNEC (>70.5 ppb)
Calf of Eday SPA	2 %	1,868 hrs	Bonn Code: 3 Metallic	1 %	1,963 hrs	Light Oiling (0.001 – 1 litres / m^2)	19 %	1,326 hrs	Below OSPAR PNEC (<70.5 ppb)
Copinsay SPA	33 %	1,234 hrs	Bonn Code: 3 Metallic	6 %	1,393 hrs	Light Oiling (0.001 – 1 litres / m^2)	43 %	1,247 hrs	Below OSPAR PNEC (<70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
East Caithness Cliffs SPA	10 %	1,719 hrs	Bonn Code: 3 Metallic	3 %	1,844 hrs	Light Oiling (0.001 – 1 litres / m^2)	10 %	1,726 hrs	Below OSPAR PNEC (<70.5 ppb)
East Mainland Coast Shetland SPA	12 %	712 hrs	Bonn Code: 3 Metallic	8 %	955 hrs	Light Oiling (0.001 – 1 litres / m^2)	30 %	801 hrs	Above OSPAR PNEC (>70.5 ppb)
East Sanday Coast SPA	5 %	1,551 hrs	Bonn Code: 3 Metallic	2 %	1,510 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Fair Isle SPA	48 %	1,052 hrs	Bonn Code: 3 Metallic	12 %	1,572 hrs	Light Oiling (0.001 – 1 litres / m^2)	71 %	1,041 hrs	Above OSPAR PNEC (>70.5 ppb)
Fetlar SPA	15 %	747 hrs	Bonn Code: 3 Metallic	4 %	1,104 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Firth of Forth SPA	27 %	1,459 hrs	Bonn Code: 3 Metallic	10 %	1,465 hrs	Light Oiling (0.001 – 1 litres / m^2)	51 %	1,420 hrs	Above OSPAR PNEC (>70.5 ppb)
Flamborough and Filey Coast SPA	N/A	N/A	N/A	N/A	N/A	N/A	18 %	2,350 hrs	Below OSPAR PNEC (<70.5 ppb)
Forth Islands SPA	49 %	804 hrs	Bonn Code: 3 Metallic	33 %	1,233 hrs	Moderate Oiling (1 – 10 litres / m^2)	67 %	828 hrs	Above OSPAR PNEC (>70.5 ppb))

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Fowlsheugh SPA	61 %	554 hrs	Bonn Code: 3 Metallic	18 %	816 hrs	Moderate Oiling (1 – 10 litres / m^2)	57 %	668 hrs	Above OSPAR PNEC (>70.5 ppb)
Greater Wash SPA	N/A	N/A	N/A	N/A	N/A	N/A	13 %	2607 hrs	Below OSPAR PNEC (<70.5 ppb)
Hermaness, Saxa Vord and Valla Field SPA	3 %	1,213 hrs	Bonn Code: 2 Rainbow	1 %	2,059 hrs	Light Oiling (0.001 – 1 litres / m^2)	18 %	1,183 hrs	Below OSPAR PNEC (<70.5 ppb)
Hoy SPA	10 %	1,511 hrs	Bonn Code: 3 Metallic	1 %	3,028 hrs	Light Oiling (0.001 – 1 litres / m^2)	16 %	2,043 hrs	Below OSPAR PNEC (<70.5 ppb)
Humber Estuary SPA	1 %	3,271 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	1 %	3,355 hrs	Below OSPAR PNEC (<70.5 ppb)
Loch of Strathbeg SPA	N/A	N/A	N/A	8 %	661 hrs	Moderate Oiling (1 – 10 litres / m^2)	N/A	N/A	N/A
Marwick Head SPA	N/A	N/A	N/A	N/A	N/A	N/A	10 %	2,361 hrs	Below OSPAR PNEC (<70.5 ppb)
Moray Firth SPA	14 %	1,607 hrs	Bonn Code: 3 Metallic	5 %	1,659 hrs	Light Oiling (0.001 – 1 litres / m^2)	18 %	1,504 hrs	Below OSPAR PNEC (<70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Mousa SPA	N/A	N/A	N/A	8 %	1,209 hrs	Light Oiling (0.001 – 1 litres / m^2)	50 %	982 hrs	Above OSPAR PNEC (>70.5 ppb)
North Caithness Cliffs SPA	14 %	1,612 hrs	Bonn Code: 3 Metallic	2 %	1,617 hrs	Light Oiling (0.001 – 1 litres / m^2)	17 %	1,832 hrs	Below OSPAR PNEC (<70.5 ppb)
North Orkney SPA	8 %	1,373 hrs	Bonn Code: 3 Metallic	2 %	1,391 hrs	Light Oiling (0.001 – 1 litres / m^2)	16 %	1,429 hrs	Below OSPAR PNEC (<70.5 ppb)
Northumberland Marine SPA	29 %	1,298 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	59 %	1,210 hrs	Above OSPAR PNEC (>70.5 ppb)
Noss SPA	17 %	1,325 hrs	Bonn Code: 3 Metallic	6 %	1,366 hrs	Light Oiling (0.001 – 1 litres / m^2)	32 %	896 hrs	Above OSPAR PNEC (>70.5 ppb)
Outer Firth of Forth and St Andrews Bay Complex SPA	59 %	424 hrs	Bonn Code: 3 Metallic	33 %	953 hrs	Moderate Oiling (1 – 10 litres / m^2)	68 %	398 hrs	Above OSPAR PNEC (>70.5 ppb)
Outer Thames Estuary SPA	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,008 hrs	Below OSPAR PNEC (<70.5 ppb)
Papa Stour SPA	2 %	2,904 hrs	Bonn Code: 3 Metallic	1 %	2,908 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Rousay SPA	5 %	1,212 hrs	Bonn Code: 3 Metallic	1 %	1,219 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Scapa Flow SPA	25 %	1,334 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	35 %	1,321 hrs	Above OSPAR PNEC (>70.5 ppb)
Seas Off Foula SPA	36 %	1,123 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	70 %	1,033 hrs	Above OSPAR PNEC (>70.5 ppb)
Sumburgh Head SPA	41 %	1,093 hrs	Bonn Code: 3 Metallic	12 %	1,420 hrs	Moderate Oiling (1 – 10 litres / m^2)	70 %	991 hrs	Above OSPAR PNEC (>70.5 ppb)
Teesmouth and Cleveland Coast SPA	3 %	2,111 hrs	Bonn Code: 3 Metallic	1 %	2,201 hrs	Light Oiling (0.001 – 1 litres / m^2)	33 %	2,093 hrs	Below OSPAR PNEC (<70.5 ppb)
Troup, Pennan and Lion's Heads SPA	23 %	1,219 hrs	Bonn Code: 3 Metallic	7 %	1,284 hrs	Light Oiling (0.001 – 1 litres / m^2)	19 %	826 hrs	Below OSPAR PNEC (<70.5 ppb)
West Westray SPA	3 %	1,208 hrs	Bonn Code: 3 Metallic	2 %	2,630 hrs	Light Oiling (0.001 – 1 litres / m^2)	18 %	1,420 hrs	Below OSPAR PNEC (<70.5 ppb)
Ythan Estuary, Sands of Forvie and Meikle Loch SPA	64 %	620 hrs	Bonn Code: 3 Metallic	39 %	637 hrs	Moderate Oiling (1 – 10 litres / m^2)	61 %	679 hrs	Above OSPAR PNEC (>70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Special Area of Conservation (SAC) with Marine Components									
Berwickshire and North Northumberland Coast SAC	30 %	905 hrs	Bonn Code: 3 Metallic	10 %	1,281 hrs	Moderate Oiling (1 – 10 litres / m^2)	58 %	979 hrs	Above OSPAR PNEC (>70.5 ppb)
Braemar Pockmarks SAC	N/A	N/A	N/A	N/A	N/A	N/A	100 %	422 hrs	Above OSPAR PNEC (>70.5 ppb)
Dogger Bank SAC	N/A	N/A	N/A	N/A	N/A	N/A	56 %	941 hrs	Below OSPAR PNEC (<70.5 ppb)
East Caithness Cliffs SAC	N/A	N/A	N/A	2 %	2,970 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Fair Isle SAC	N/A	N/A	N/A	11 %	1,984 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Faray and Holm of Faray SAC	2 %	1,858 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	17 %	1,416 hrs	Below OSPAR PNEC (<70.5 ppb)
Firth of Tay and Eden Estuary SAC	54 %	924 hrs	Bonn Code: 3 Metallic	17 %	953 hrs	Moderate Oiling (1 – 10 litres / m^2)	54 %	792 hrs	Below OSPAR PNEC (<70.5 ppb))

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Flamborough Head SAC	N/A	N/A	N/A	N/A	N/A	N/A	14 %	2,513 hrs	Below OSPAR PNEC (<70.5 ppb)
Hoy SAC	N/A	N/A	N/A	1 %	3,334 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Humber Estuary SAC	1 %	3,271 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	1 %	3,345 hrs	Below OSPAR PNEC (<70.5 ppb)
Inner Dowsing Race Bank and North Ridge SAC	N/A	N/A	N/A	N/A	N/A	N/A	7 %	2,817 hrs	Below OSPAR PNEC (<70.5 ppb)
Isle of May SAC	N/A	N/A	N/A	N/A	N/A	N/A	62 %	831 hrs	Below OSPAR PNEC (<70.5 ppb)
Lower River Spey – Spey Bay SAC	N/A	N/A	N/A	3 %	2,429 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
Moray Firth SAC	N/A	N/A	N/A	N/A	N/A	N/A	10 %	1,627 hrs	Below OSPAR PNEC (<70.5 ppb)
Mousa SAC	N/A	N/A	N/A	24 %	1,270 hrs	Moderate Oiling (1 – 10 litres / m^2)	51 %	981 hrs	Above OSPAR PNEC (>70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
North Fetlar SAC	N/A	N/A	N/A	2 %	1,707 hrs	Light Oiling (0.001 – 1 litres / m^2)	N/A	N/A	N/A
North Norfolk Sandbanks and Saturn Reef SAC	N/A	N/A	N/A	N/A	N/A	N/A	6 %	2,584 hrs	Below OSPAR PNEC (<70.5 ppb)
Papa Stour SAC	N/A	N/A	N/A	2 %	2,908 hrs	Light Oiling (0.001 – 1 litres / m^2)	32 %	1,621 hrs	Below OSPAR PNEC (<70.5 ppb)
Pobie Bank Reef SAC	N/A	N/A	N/A	N/A	N/A	N/A	40 %	587 hrs	Above OSPAR PNEC (>70.5 ppb)
River Dee SAC	24 %	2,042 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	7 %	1,981 hrs	Below OSPAR PNEC (<70.5 ppb)
Sanday SAC	8 %	1,208 hrs	Bonn Code: 3 Metallic	3 %	1,510 hrs	Light Oiling (0.001 – 1 litres / m^2)	19 %	1,201 hrs	Below OSPAR PNEC (<70.5 ppb)
Sands of Forvie SAC	N/A	N/A	N/A	4 %	2,627 hrs	Moderate Oiling (1 – 10 litres / m^2)	N/A	N/A	N/A
Scanner Pockmark SAC	N/A	N/A	N/A	N/A	N/A	N/A	100 %	306 hrs	Above OSPAR PNEC (>70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Solan Bank Reef SAC	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,363 hrs	Below OSPAR PNEC (<70.5 ppb)
Southern North Sea SAC	N/A	N/A	N/A	N/A	N/A	N/A	35 %	924 hrs	Below OSPAR PNEC (<70.5 ppb)
Sullom Voe SAC	1 %	2,425 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	12 %	2,025 hrs	Below OSPAR PNEC (<70.5 ppb)
The Wash and North Norfolk Coast SAC	N/A	N/A	N/A	N/A	N/A	N/A	2 %	3,150 hrs	Below OSPAR PNEC (<70.5 ppb))
Yell Sound Coast SAC	4 %	1,805 hrs	Bonn Code: 3 Metallic	2 %	1,815 hrs	Light Oiling (0.001 – 1 litres / m^2)	19 %	1,159 hrs	Below OSPAR PNEC (<70.5 ppb))
RAMSAR									
Cromarty Firth RAMSAR	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,182 hrs	Below OSPAR PNEC (<70.5 ppb)
Dornoch Firth and Loch Fleet RAMSAR	N/A	N/A	N/A	N/A	N/A	N/A	2 %	2,924 hrs	Below OSPAR PNEC (<70.5 ppb)
East Sanday Coast RAMSAR	5 %	1,551 hrs	Bonn Code: 3 Metallic	2 %	1,510 hrs	Light Oiling (0.001 – 1 litres / m^2)	18 %	1,315 hrs	Below OSPAR PNEC (<70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Firth of Forth RAMSAR	N/A	N/A	N/A	13 %	1,465 hrs	Moderate Oiling (1 – 10 litres / m^2)	N/A	N/A	N/A
Firth of Tay and Eden Estuary RAMSAR	N/A	N/A	N/A	17 %	953 hrs	Moderate Oiling (1 – 10 litres / m^2)	N/A	N/A	N/A
Humber Estuary RAMSAR	1 %	3,271 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	1 %	3,355 hrs	Below OSPAR PNEC (<70.5 ppb)
Loch of Strathbeg RAMSAR	N/A	N/A	N/A	8 %	661 hrs	Moderate Oiling (1 – 10 litres / m^2)	N/A	N/A	N/A
Moray and Nairn Coast RAMSAR	N/A	N/A	N/A	N/A	N/A	N/A	2 %	2,082 hrs	Below OSPAR PNEC (<70.5 ppb)
Ronas Hill – North Roe and Tingon RAMSAR	N/A	N/A	N/A	N/A	N/A	N/A	10 %	1,593 hrs	Below OSPAR PNEC (<70.5 ppb)
Nature Conservation Marine Protected Areas (NC MPA)									
Central Fladen NC MPA	N/A	N/A	N/A	N/A	N/A	N/A	100 %	511 hrs	Above OSPAR PNEC (>70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
East Caithness Cliffs NC MPA	10 %	1,719 hrs	Bonn Code: 3 Metallic	3 %	1,844 hrs	Light Oiling (0.001 – 1 litres / m^2)	10 %	1,726 hrs	Below OSPAR PNEC (<70.5 ppb)
East of Gannet and Montrose Fields NC MPA	100 %	13 hrs	Bonn Code: 5 (Continuous True Oil Colour)	N/A	N/A	N/A	100 %	13 hrs	Above OSPAR PNEC (>70.5 ppb)
Faroe- Shetland Sponge Belt NC MPA	N/A	N/A	N/A	N/A	N/A	N/A	3 %	2,344 hrs	Below OSPAR PNEC (<70.5 ppb)
Fetlar to Haroldswick NC MPA	15 %	747 hrs	Bonn Code: 3 Metallic	4 %	1,104 hrs	Light Oiling (0.001 – 1 litres / m^2)	19 %	737 hrs	Above OSPAR PNEC (>70.5 ppb)
Firth of Forth Banks Complex NC MPA	71 %	265 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	77 %	309 hrs	Above OSPAR PNEC (>70.5 ppb)
Mousa to Boddam NC MPA	24 %	1,021 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	55 %	982 hrs	Above OSPAR PNEC (>70.5 ppb)
North- east Faroe-Shetland Channel NC MPA	N/A	N/A	N/A	N/A	N/A	N/A	8 %	943 hrs	Below OSPAR PNEC (<70.5 ppb)
North West Orkney NC MPA	22 %	1,384 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	48 %	1,081 hrs	Below OSPAR PNEC (<70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Norwegian Boundary Sediment Plain NC MPA	N/A	N/A	N/A	N/A	N/A	N/A	100 %	227 hrs	Above OSPAR PNEC (>70.5 ppb)
Noss Head NC MPA	12 %	1,645 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	7 %	1,809 hrs	Below OSPAR PNEC (<70.5 ppb)
Papa Westray NC MPA	2 %	1,880 hrs	Bonn Code: 3 Metallic	1 %	3,158 hrs	Light Oiling (0.001 – 1 litres / m^2)	16 %	1,291 hrs	Below OSPAR PNEC (<70.5 ppb)
Solan Bank Reef NC MPA	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,363 hrs	Below OSPAR PNEC (<70.5 ppb)
Southern Trench NC MPA	76 %	493 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	78 %	446 hrs	Above OSPAR PNEC (>70.5 ppb)
Turbot Bank NC MPA	99 %	348 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	97 %	368 hrs	Above OSPAR PNEC (>70.5 ppb)
West Shetland Shelf NC MPA	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,086 hrs	Below OSPAR PNEC (<70.5 ppb)
Wyre and Rousay Sounds NC MPA	4 %	1,215 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	3 %	1,918 hrs	Below OSPAR PNEC (<70.5 ppb)
Marine Conservation Zones (MCZ)									

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
Berwick to St Mary's MCZ	30 %	1,281 hrs	Bonn Code: 3 Metallic	7 %	1,558 hrs	Light Oiling (0.001 – 1 litres / m^2)	55 %	1,122 hrs	Below OSPAR PNEC (<70.5 ppb)
Cromer Shoal Chalk Beds MCZ	N/A	N/A	N/A	N/A	N/A	N/A	2 %	3,127 hrs	Below OSPAR PNEC (<70.5 ppb))
Farnes East MCZ	N/A	N/A	N/A	N/A	N/A	N/A	62 %	1,035 hrs	Below OSPAR PNEC (<70.5 ppb)
Fulmar MCZ	N/A	N/A	N/A	N/A	N/A	N/A	100 %	72 hrs	Above OSPAR PNEC (>70.5 ppb)
Holderness Inshore MCZ	N/A	N/A	N/A	N/A	N/A	N/A	8 %	2,790 hrs	Below OSPAR PNEC (<70.5 ppb)
Holderness Offshore MCZ	N/A	N/A	N/A	N/A	N/A	N/A	20 %	2,110 hrs	Below OSPAR PNEC (<70.5 ppb)
Kentish Knock East MCZ	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,046 hrs	Below OSPAR PNEC (<70.5 ppb)
Markham's Triangle MCZ	N/A	N/A	N/A	N/A	N/A	N/A	9 %	2,626 hrs	Below OSPAR PNEC (<70.5 ppb)

Protected Area	Surface Oil (Minimum Thickness of 0.3 µm)			Shoreline Oil (Minimum Thickness of 1.0 µm)			Subsurface Oil (Minimum Water Column Concentration 1.0 ppb)		
	Maximum Probability	Shortest Arrival Time	Maximum Severity of Surface Oiling (refer to Table F.3)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Shoreline Oiling (refer to Table F.5)	Maximum Probability	Shortest Arrival Time	Maximum Severity of Water Column Oiling (refer to Table F.4)
North East of Farnes Deep MCZ	21 %	750 hrs	Bonn Code: 3 Metallic	N/A	N/A	N/A	49 %	914 hrs	Below OSPAR PNEC (<70.5 ppb)
Orford Inshore MCZ	N/A	N/A	N/A	N/A	N/A	N/A	1 %	3,024 hrs	Below OSPAR PNEC (<70.5 ppb)
Runswick Bay MCZ	N/A	N/A	N/A	N/A	N/A	N/A	30 %	1,582 hrs	Below OSPAR PNEC (<70.5 ppb)
Swallow Land MCZ	N/A	N/A	N/A	N/A	N/A	N/A	96 %	149 hrs	Above OSPAR PNEC (>70.5 ppb)

Note 1: Shortest arrival time and maximum probability values are not necessarily linked to the same run. The results represent a worst case scenario for each feature based on the analysis of all model runs.

F.4 Trajectory Modelling Results

The stochastic modelling results detailed above in Section F.3 were composed of 100 individual trajectory simulations per season. The worst-case trajectory simulation for each season has been extracted to produce a fates analysis for the duration of the spill plus 10 days (total 142 days model duration).

The worst-case trajectory simulations have been identified by the 'greatest mass of beached oil at any one location'. The following trajectory simulations have been extracted and analysed:

- **Winter (Dec-Feb):** Run No. 33 (Start Date: 03/12/2019; Start Time: 00:00), 10,225.81 tonnes (75,662.67 bbl or 12,030.36 m^3) of oil beached.
- **Spring (Mar-May):** Run No. 52 (Start Date: 19/03/2021; Start Time: 15:00), 2,237.48 tonnes (16,555.53 bbl or 2,632.33 m^3) of oil beached.
- **Summer (Jun-Aug):** Run No. 81 (Start Date: 05/08/2023; Start Time: 23:00), 519.96 tonnes (3,847.28 bbl or 611.72 m^3) of oil beached.
- **Autumn (Sep-Nov):** Run No. 34 (Start Date: 08/11/2019; Start Time: 09:00), 6,096.93 tonnes (45,112.32 bbl or 7,172.86 m^3) of oil beached.

Figure F.12 displays the trajectory simulations spatially, with total swept area of surface and shoreline oiling at 24-hour time steps after 142 days.

Table F.8 provides summary statistics for the trajectory simulations. The fate of the released oil is consistent between seasons with the majority evaporated and degraded after 142 days. The winter and autumn simulations produce the greatest impact on the shoreline.

Table F.8: Fate Analysis Summary for Trajectory Simulations

Season	Trajectory Run No.	Minimum Time for Surface Oiling	Maximum Surface Slick Area	Minimum Time for Shoreline Oiling	Impacted Length of Coastline after 142 days	Fate of Released oil after 142 days (% of total release) Note 1					
						Ashore	Surface	Water Column	Evaporated	Degraded	Sediment
Winter	33	2 hrs	21,839.60 km^2	643 hrs	617.16 km	0.88	0.68	16.50	40.25	41.70	0.00
Spring	52	2 hrs	14,034.64 km^2	637 hrs	205.64 km	0.20	0.25	17.19	44.25	38.11	0.00
Summer	81	2 hrs	6,771.71 km^2	561 hrs	67.72 km	0.05	0.11	17.63	42.15	40.06	0.00
Autumn	34	2 hrs	13,925.62 km^2	710 hrs	395.34 km	0.58	0.02	17.35	40.27	41.77	0.00

Note 1: Refer to fates analysis graphs (**Winter**: Figure F.13; **Spring**: Figure F.14; **Summer**: Figure F.15; **Autumn**: Figure F.16) showing spill progression over the total simulation time of 142 days (3,408 hours).

Figure F.12: Worst Case Trajectory Simulations Showing Swept Area for Surface and Shoreline Oiling at 24-hour intervals

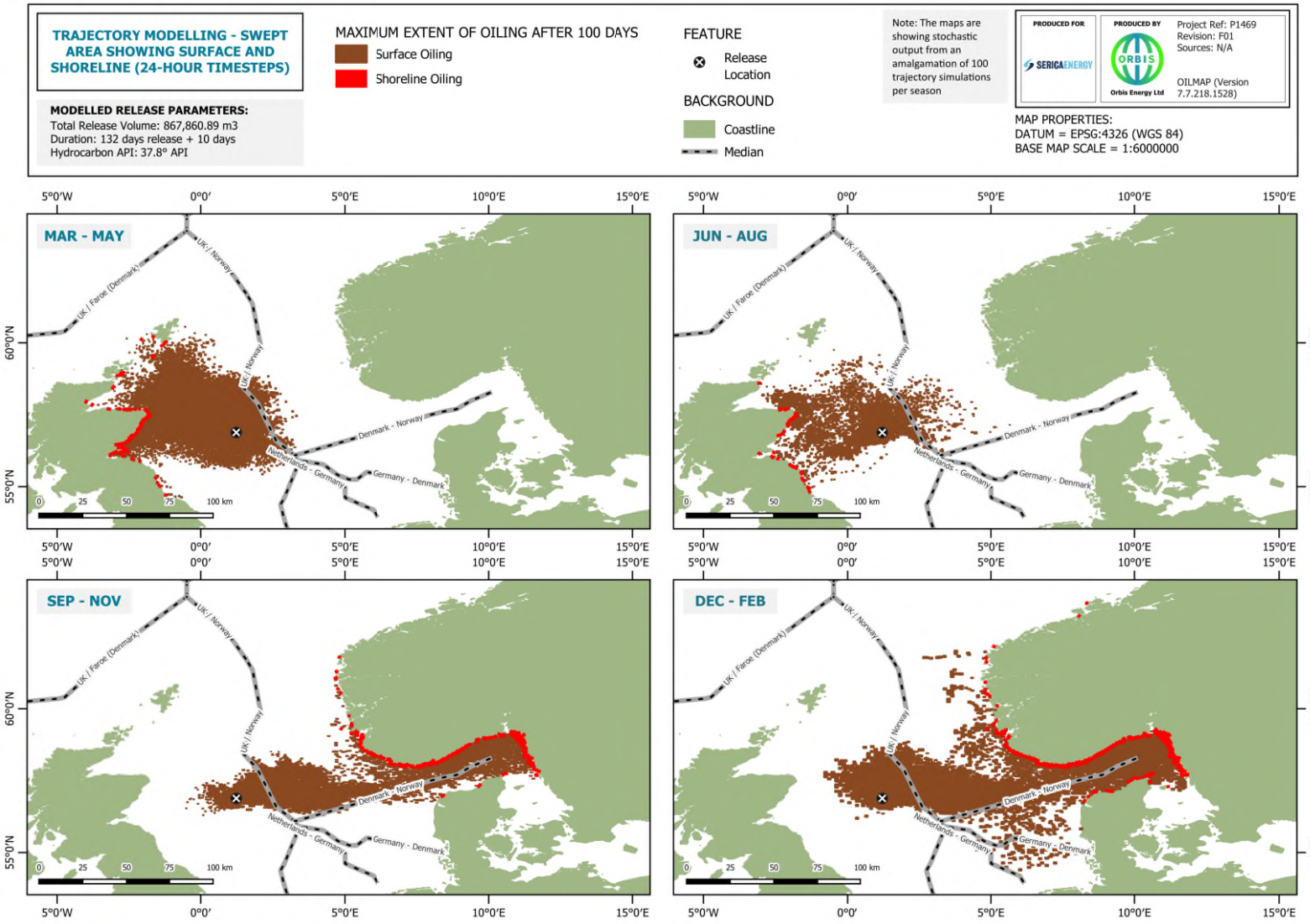


Figure F.13: Fate of the oil released from Winter Run No. 33 (showing model duration 142 days)

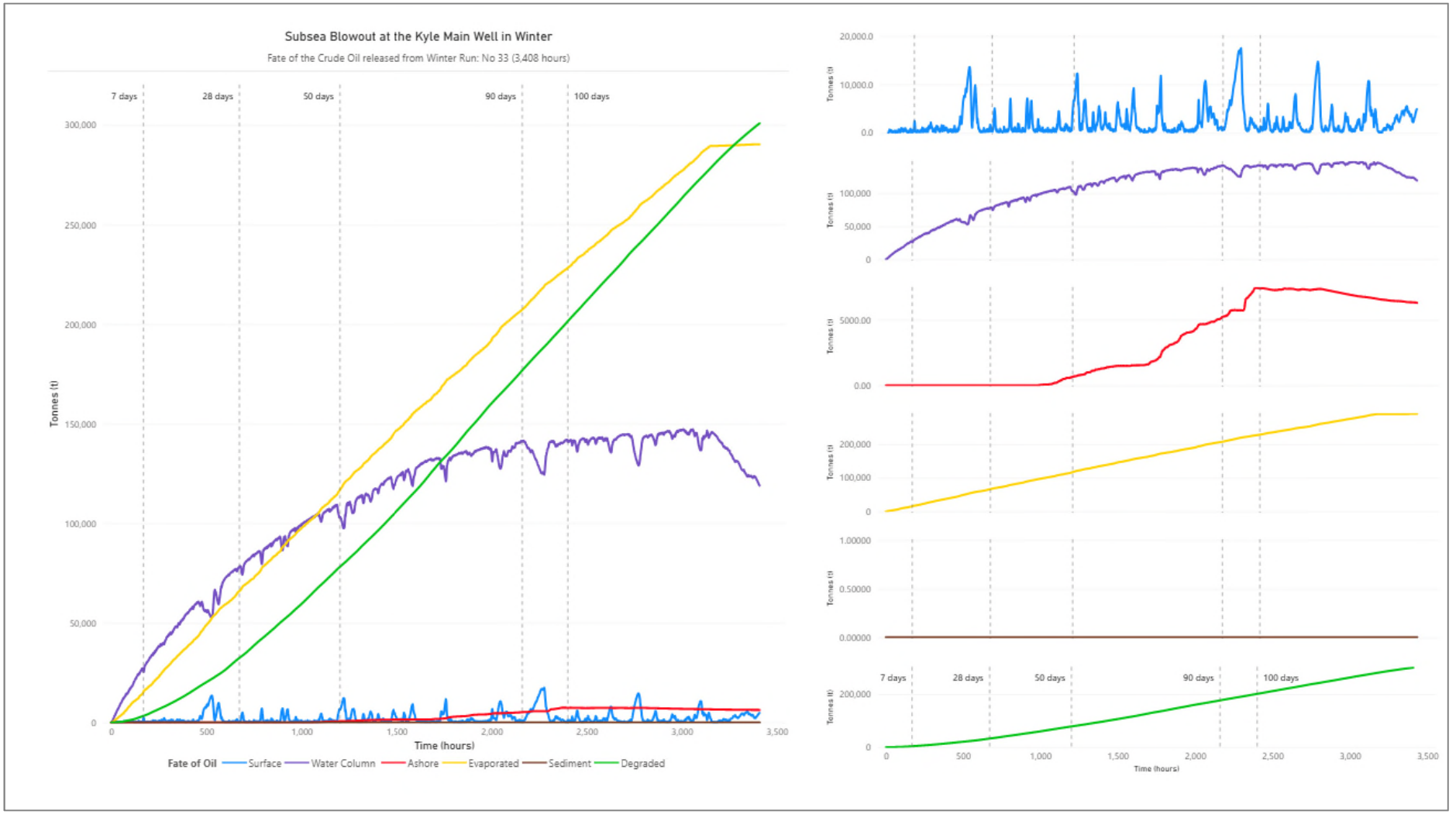


Figure F.14: Fate of the oil released from Spring Run No. 52 (showing model duration 142 days)

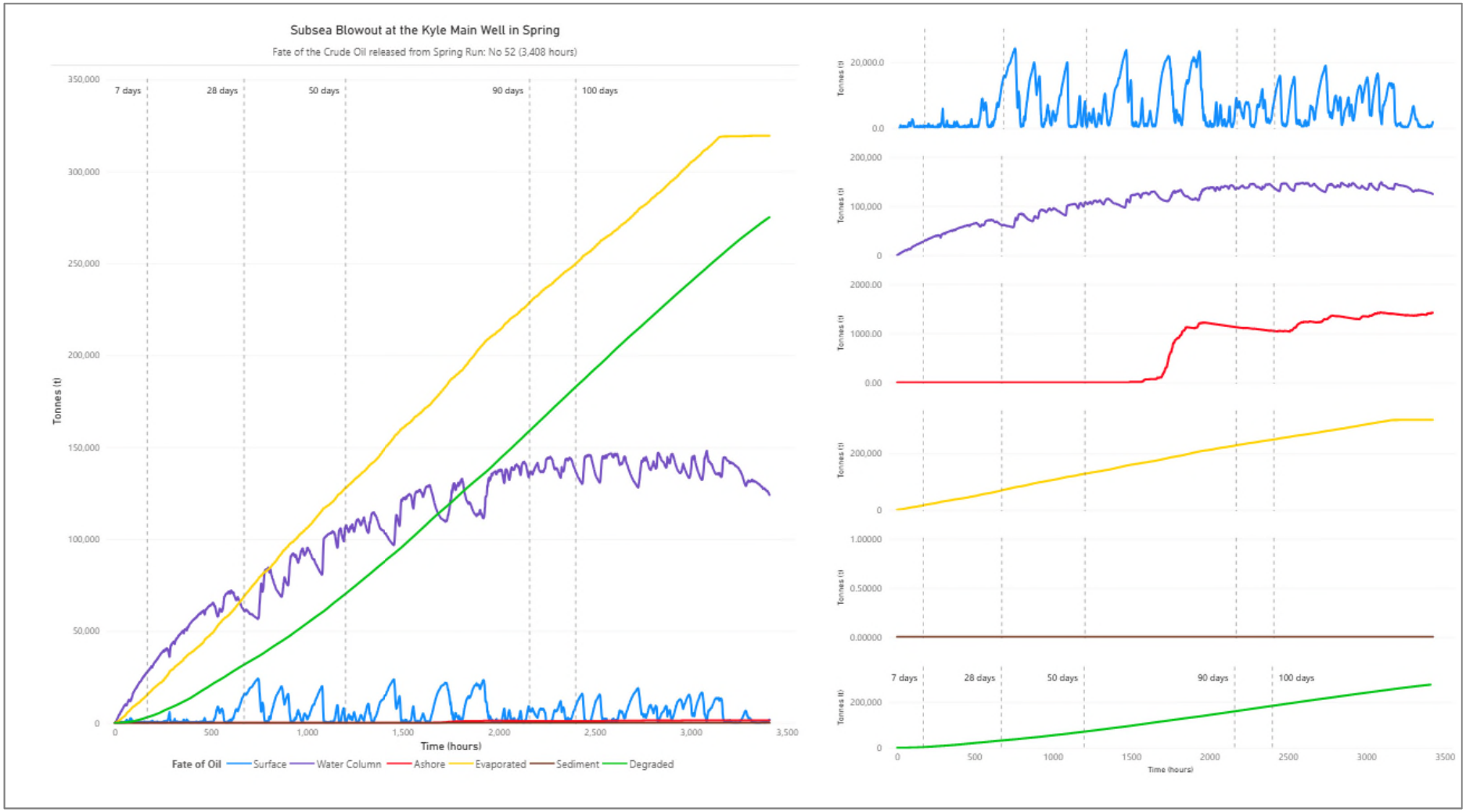


Figure F.15: Fate of the oil released from Summer Run No. 81 (showing model duration 142 days)

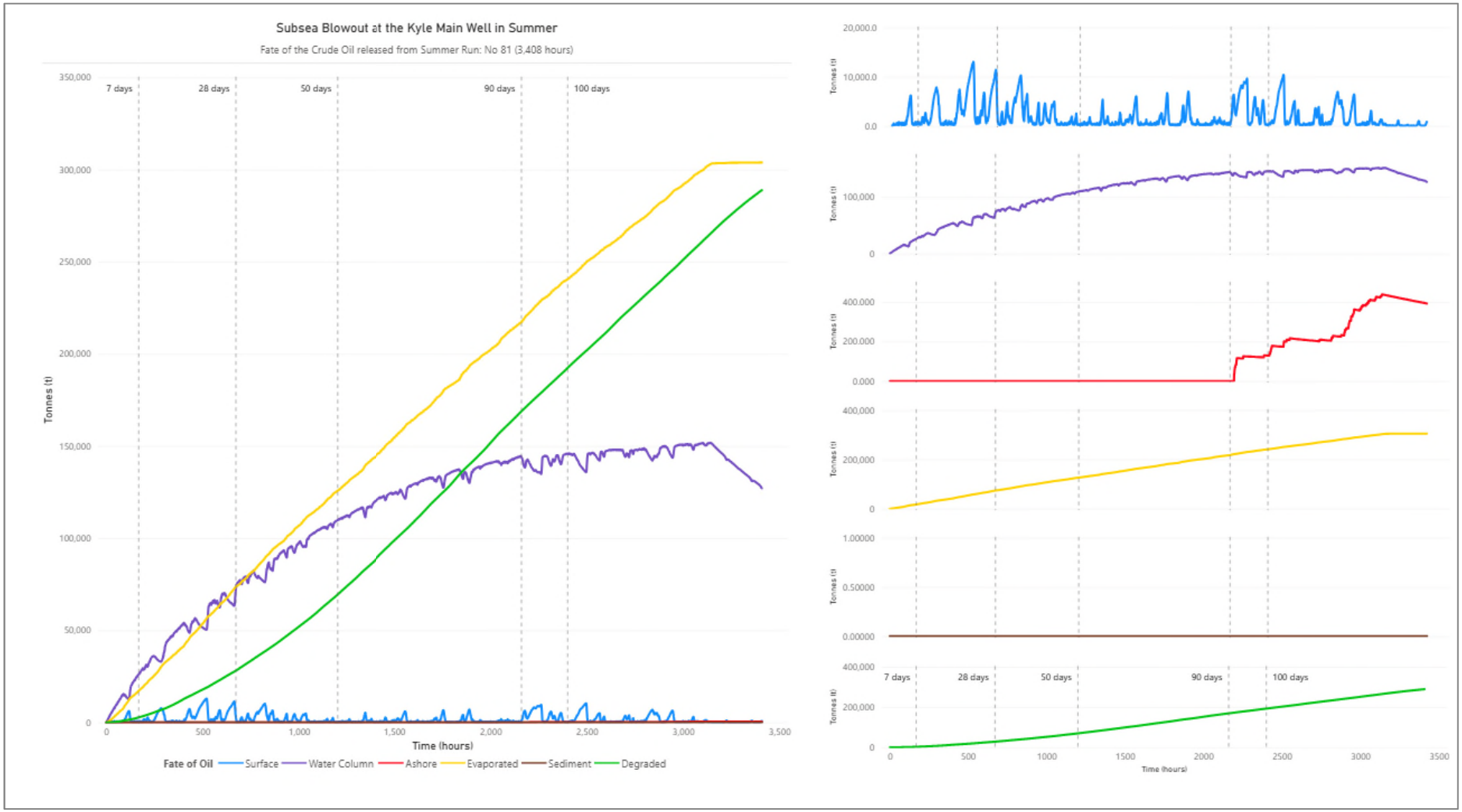
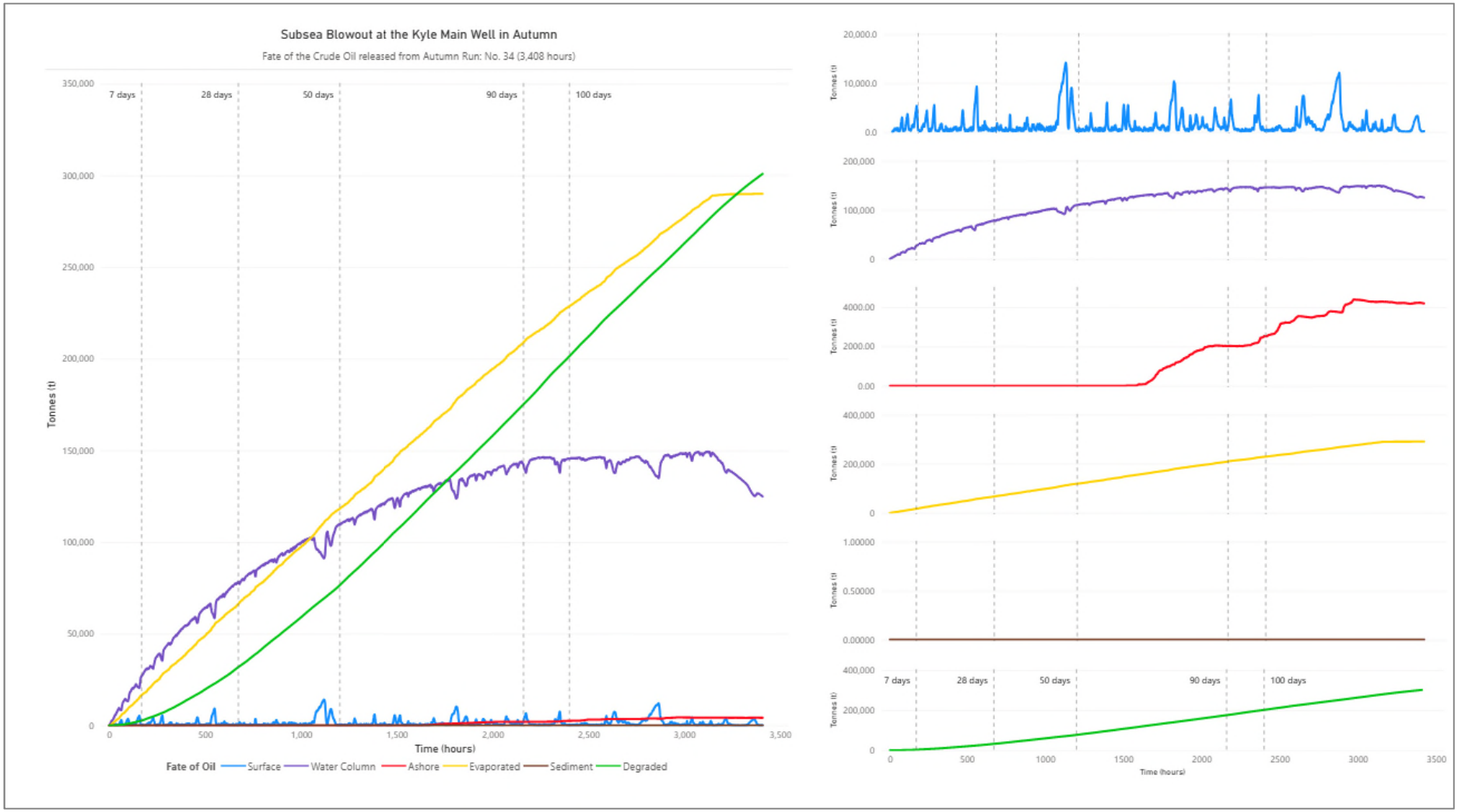


Figure F.16: Fate of the oil released from Autumn Run No. 34 (showing model duration 142 days)

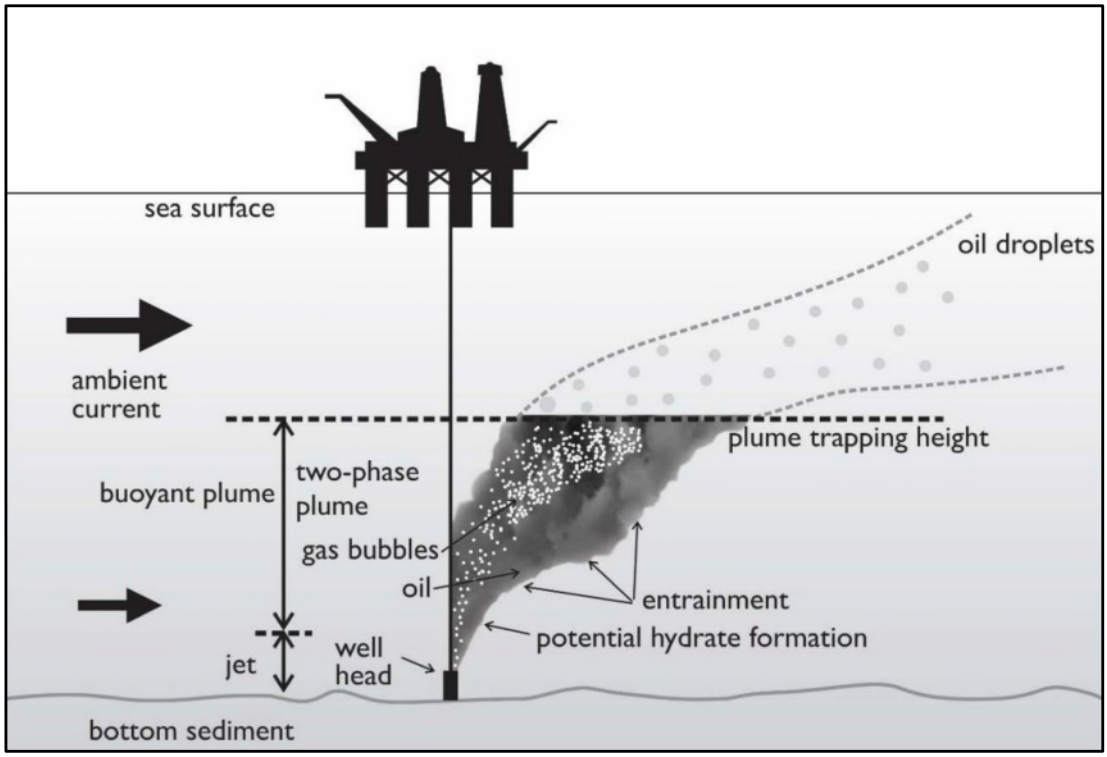


F.5 Vertical Profile Modelling

F.5.1 Background

The OILMAP Deep plume model evaluates the jet and buoyant plume of the oil and gas release near the well release point. Figure F.17 presents a schematic of the various stages of a subsurface release in the water column. The OILMAP Deep blowout model estimates the radius and location of a buoyant oil and gas plume in response to the release parameters and environmental characteristics, tracking the development of the plume until the point where the integrated density of the plume matches the ambient density, through entrainment of surrounding seawater in the stratified ocean. At this depth, the plume buoyancy has decreased to an extent that the oil and gas mixture no longer rises. At this stage the blowout model outputs the locations, volumes, and droplet sizes of the released oil droplets, which then become input to the oil trajectory and fate model.

Figure F.17: Stages of a deep-water blowout plume



Blowout Description

In a subsurface well blowout, discharged materials consisting of a mixture of gaseous and liquid hydrocarbons go through three phases, namely (1) momentum jet, (2) buoyant plume, and (3) oil droplets free-rise and advection-diffusion (Zheng et al., 2003), (as illustrated schematically in Figure F.17):

- **Phase 1 momentum jet:** The difference between the pressure immediately inside the well and that of the ambient water drives the discharge in a momentum jet exiting the blowout orifice. The momentum of the jet dissipates relatively quickly as it entrains surrounding water, and hence the jet zone is always confined to the immediate vicinity of the wellhead, or blowout site (typically on the order of metres, depending on the release hole size). At the blowout opening, the oil in the release is exposed to significant turbulent energy, resulting in the break-up of oil into small droplets. These droplets (typically micrometres to millimetres in diameter) are transported upward with the rising plume.
- **Phase 2 buoyant density plume:** As the discharge moves upward, the density difference between the gas bubbles (and to a lesser extent, oil droplets) in the plume and the ambient waters results in a buoyant force which drives the plume. As the plume rises, it continues to

entrain sea water, increasing the plume's density and radius, and reducing the velocity and buoyancy. The plume gas is in the form of bubbles which are subject to dissolution based on Zheng and Yapa (2002) which serves to reduce the buoyancy. If the ambient currents are strong enough the plume may bend as shown in Figure F.17. Gas bubbles may also separate from the plume if their rise speeds exceed the plume's rise rate. The oil droplets continue to be transported upwards with the plume, but their individual rise velocities contribute little to their upward motion.

- **Phase 3: oil droplets free-rise and advection-diffusion:** When the plume reaches the sea surface or its termination or trap height (all plume buoyancy is lost), it can be deflected in a radial pattern, within a horizontal flow zone, without appreciable loss of momentum. This radial flow carries the oil particles rapidly away from the centre of the plume, while the velocity and oil concentrations in this flow zone decrease with distance from the plume centreline of the release. Subsequently, oil particles ascend to the surface solely driven by their own buoyancy. Rise velocities of oil droplets are much slower than the velocity of a buoyant gas-liquid plume, resulting in particle transport that may take considerably longer to reach the surface and moving further (horizontally) from the release site because of ambient currents.

Of the three phases described above, the OILMAP Deep plume model simulates only Phase 2, the buoyancy driven portion. The assumption is that Phase 1, the momentum jet, is very limited in distance from the release (a few times the diameter of the discharge hole) and hence relatively insignificant in the prediction of the overall plume development and the trap height. Phase 3, the passive oil droplet transport and fate, is simulated using the OILMAP Trajectory and Fates model (far-field oil particle transport and fates).

F.5.2 Blowout Plume (Near-field Modelling Results)

The key inputs for the OILMAP Deep near-field model include the well release rate, GOR, diameter of release hole, and a vertical profile of water temperature and density.

For the Kyla Development blowout scenario, the GOR was 128.2 m^3/m^3 and the diameter of release hole was 0.2204974 m. The water temperature and density profile used in the model for the Kyla Development location is displayed in Figure F.23.

The near-field modelling results provide a description of the plume characteristics, including the plume location (namely plume trap height), plume geometry (plume radius), and the release droplet size distribution. The results of the near-field model are then used to provide the initial conditions for the stochastic and deterministic far-field modelling in OILMAP Trajectory and Fates model, including:

- Termination height (trap height) of the plume;
- Diameter of the plume; and
- Oil droplet size distribution.

Table F.9 presents a summary of the OILMAP Deep plume modelling results from the Kyla Development well blowout scenario by season. There is very little variation in plume formation and behaviour as well as oil droplet formation between seasons.

Table F.9: Predicted blowout plume characteristics for the Kyla Development well blowout scenario by season

Season	Maximum Height of Plume (height above the wellhead)	Time to reach Maximum Height of Plume	Maximum Plume Radius	Maximum Oil Plume Concentration Note 2	Maximum Dissolved Methane Concentration Note 3	Oil Droplet Size (µm) Note 1 (free-rise and advection-diffusion)		
						Minimum	Maximum	Median
Winter	89.55 m	33 seconds	6.58 m	44.091 ppm	0.006 mol/m^3	36.97	356.65	150.28
Spring	89.55 m	33 seconds	6.59 m	44.433 ppm	0.006 mol/m^3	37.10	357.83	150.78
Summer	89.55 m	33 seconds	6.62 m	43.242 ppm	0.006 mol/m^3	36.69	353.90	149.12
Autumn	89.55 m	33 seconds	6.58 m	41.768 ppm	0.005 mol/m^3	36.22	349.35	147.20

Note 1: The oil droplet size distribution is as a histogram in Figure F.19.
Note 2: ppm = parts per million.
Note 3: mol = moles.

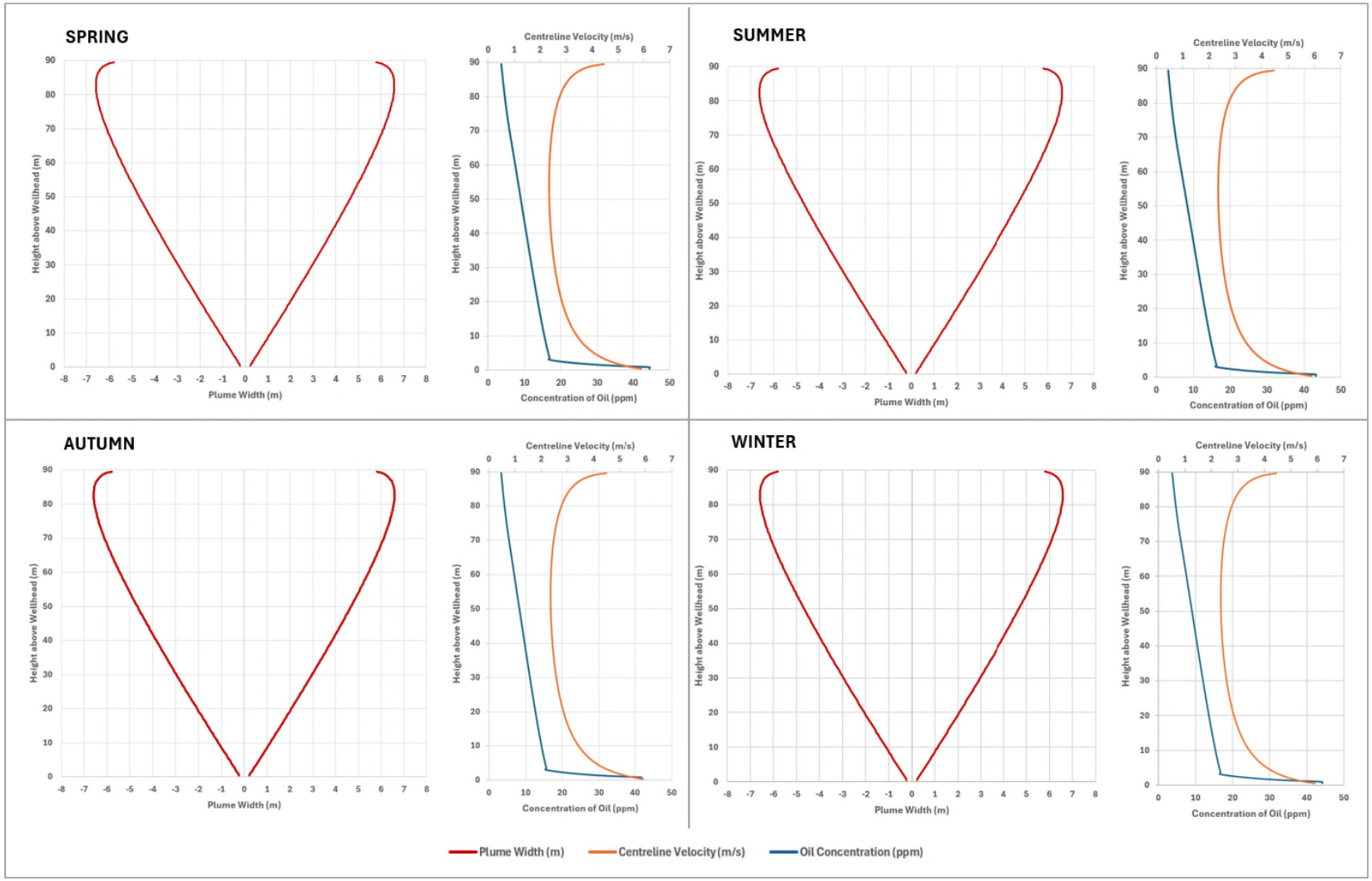
Figure F.18 shows the modelled plume width (positive and negative radius) as a function of the height above the seabed. Across all seasons, the plume exhibits a symmetrical widening from the release point, reaching a maximum width of approximately 13 m. The plume reaches a termination point just below the sea surface (89.55 m above the seabed release location).

The plume centreline velocity defines the vertical movement of the mixture of gas, oil, and water along the centre of the plume. The model shows that the centreline velocity of the plume remains relatively consistent, with peak rise values ca. 6 m/s at depth before a gradual reduction with elevation, where plume momentum is dissipated through entrainment and mixing. A slight increase in the plume centreline velocity is evident close to the sea surface, caused by the interaction with background current shear rather than a true physical acceleration of the plume (Figure F.18). The plume reaches its maximum termination height (89.55 m) after 33 second for all seasons (Table F.9).

Oil concentrations along the plume centreline are highest immediately above the release point (ca.40 ppm) and decline rapidly with height, approaching negligible values before the upper extent of the model domain (Figure F.18).

Seasonal variability in plume width, velocity, and concentration is minimal, indicating that near-field plume behaviour is largely unaffected by seasonal changes in oceanographic conditions. The near-field modelling results indicate that seasonal stratification is not a dominant control on plume behaviour or trap height. The plume rise appears to be controlled primarily by the release momentum and buoyancy flux and by turbulent entrainment, while background tidal and wind-driven mixing in the central North Sea is sufficient to prevent persistent trapping or strong deflection of the plume by seasonal density layers. As a result, the near-field plume geometry and predicted centreline oil concentrations are similar across seasons and potential environmental effects in the immediate vicinity of the release point are expected to be broadly consistent year-round.

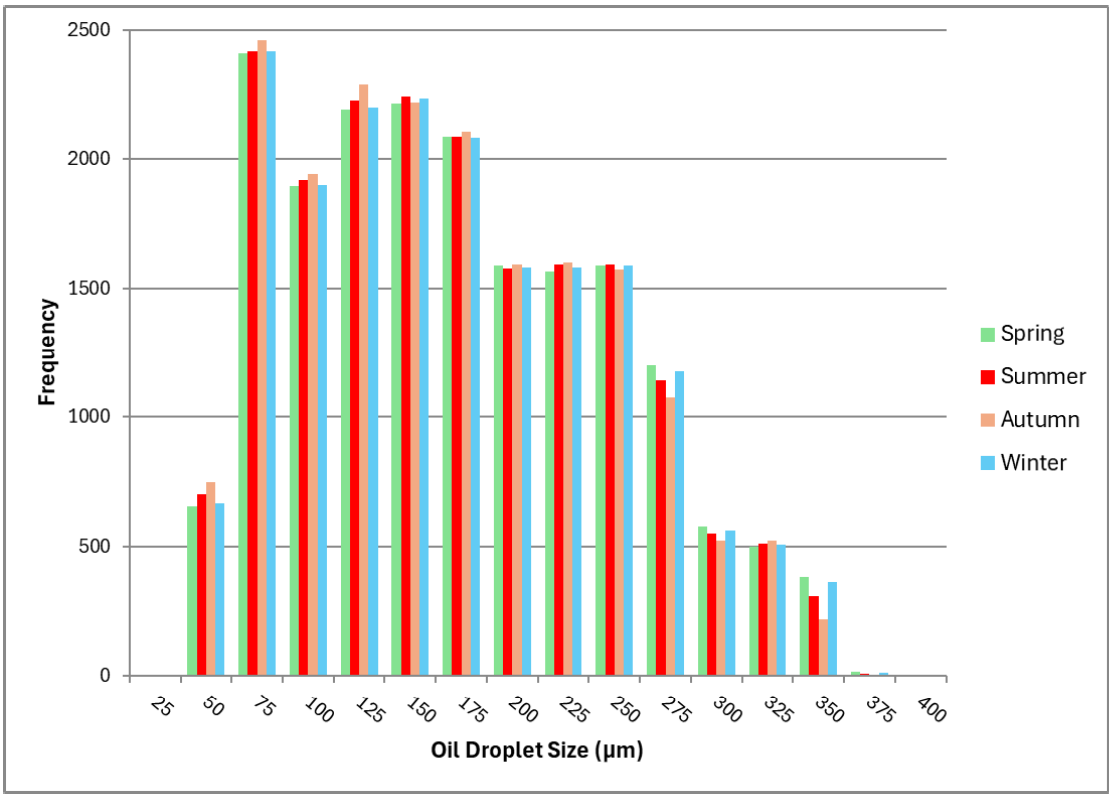
Figure F.18: Predicted blowout plume centreline velocity, oil concentration and plume radius after 132 days versus elevation above the release point for the Kyla Development well blowout scenario by season



The OILMAP Deep near-field modelling also calculates the oil droplet size distribution generated by the blowout. The oil droplets fall out of the plume at termination height and are used in the far-field oil trajectory and fate model (refer to Section F.5.1 and Figure F.17). This oil droplet size distribution has a profound effect on how oil is transported after the initial plume, as the droplet size dictates how long the oil droplet will remain suspended in the water column. Larger droplets are more buoyant and rise relatively quickly to the sea surface, while smaller droplets remain entrained in the water column for longer periods and ascend more slowly. Figure F.19 shows the model-estimated droplet size distribution. The minimum, maximum and median oil droplet sizes are presented in Table F.9. Oil droplet sizes <200 µm account for 61.4% of the spill volume, these droplet sizes are associated with high turbulence and rise very slowly to the sea surface resulting in prolonged water column entrainment. Oil droplets <70 µm (accounting for ca. 16 % of the spill volume) do not rise to the surface and remain within the water column. Oil droplet sizes >200 µm and <1,000 µm account for 38.6 % of the spill volume, these droplet sizes are associated with an intermediate turbulent energy and will rise at a quicker rate (Delvigne and Sweeny, 1988).

The maximum oil droplet size across all seasons modelled was 357.83 µm; a droplet this size was found to surface within 2-hours of dropping out of the plume.

Figure F.19: Oil Droplet Size Distribution



F.5.3 Oil in the Water Column (Far-field Modelling Results)

Of the trajectory modelling detailed in Section F.4, the Spring Trajectory Run No. 52 was identified as having the greatest surface and subsurface oiling within UK waters (refer to Table F.8). Therefore, the Spring Trajectory Run No. 52 has been selected to show the oil concentration and transport in the vertical water column.

Figure F.20, Figure F.21 and Figure F.22 show the oil concentration in the vertical water column at the 1, 25-, 50-, 75-, 100- and 142-day model time stamps. The cross-section line (282 km in length) intersects with the release location to the nearest point on land. The vertical profile model demonstrates that the highest oiling concentrations (>10,000 ppb) are found in the upper water column and only occur near the release location. The vertical profile model for Spring Trajectory Run No. 6 was representative for all seasons.

Figure F.20: Section view and subsurface oiling during spring (Trajectory Run No. 52) after day 1 & day 25

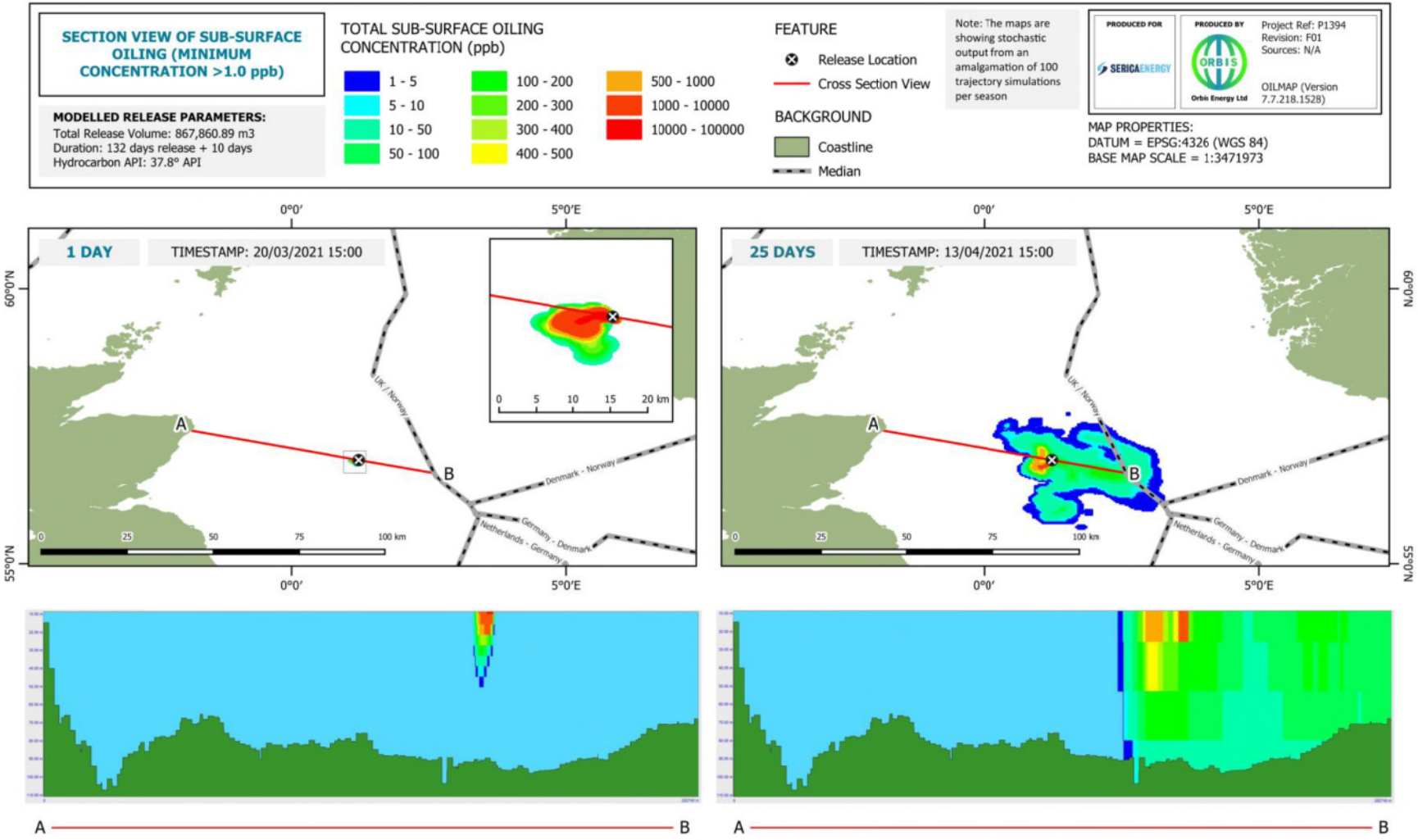


Figure F.21: Section view and subsurface oiling during spring (Trajectory Run No. 52) after day 50 & day 75

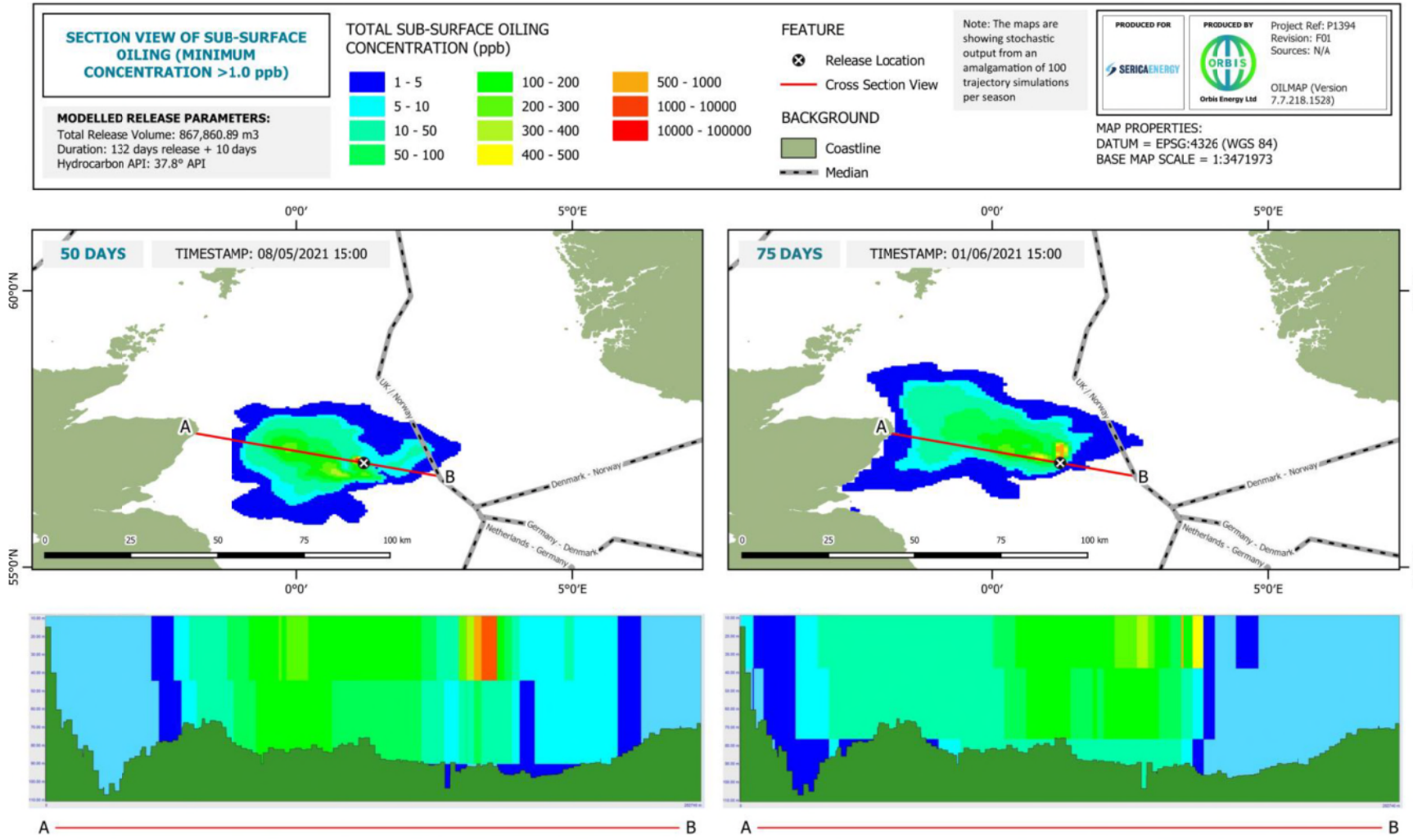
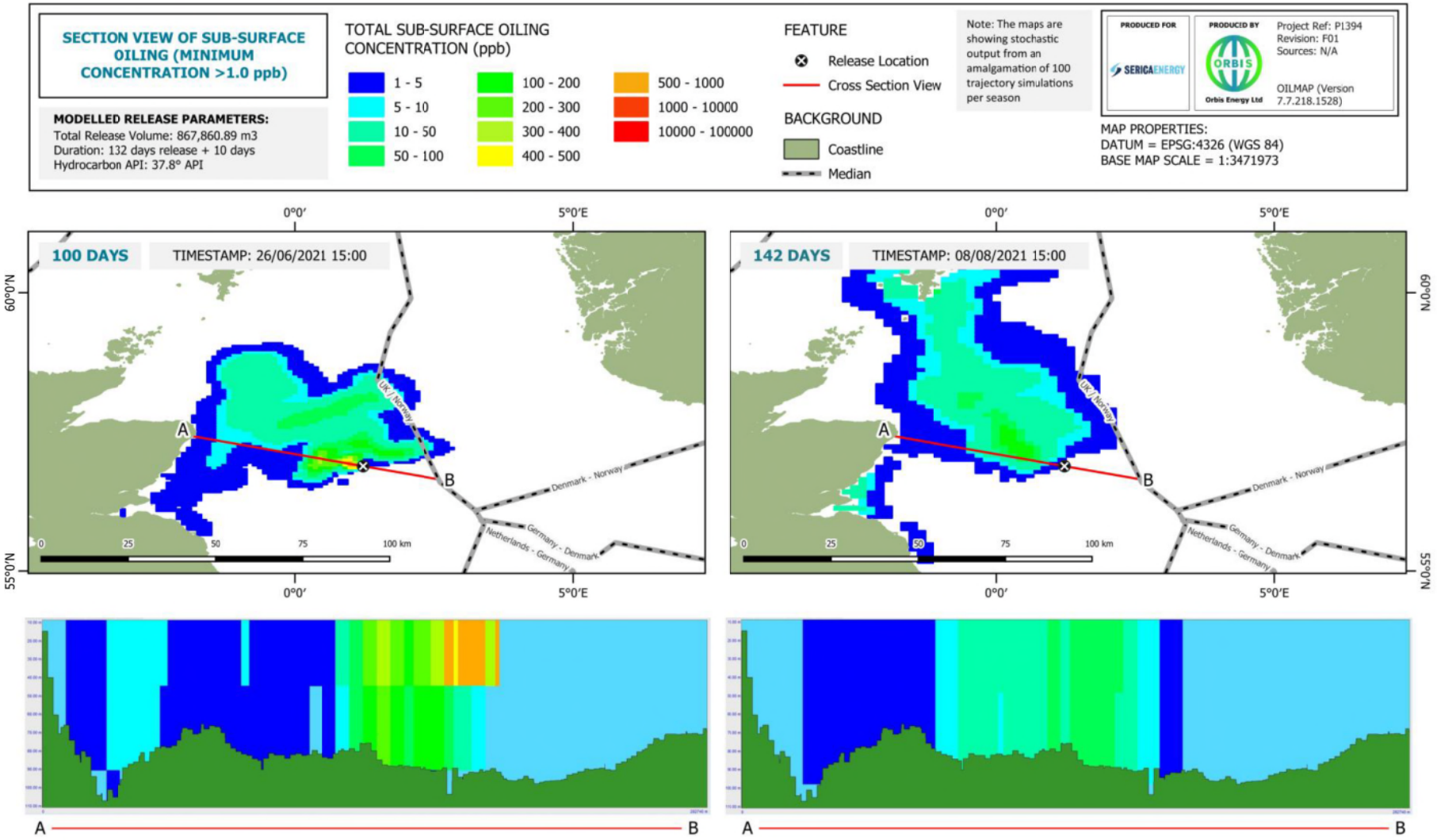


Figure F.22: Section view and subsurface oiling during spring (Trajectory Run No. 52) after day 100 & day 142



F.6 Model Input Data

F.6.1 Metocean Data

Current and Tidal Data

To capture the complex nature of the regional and coastal circulation for the areas near to the UK, two different current datasets are provided which can be combined to simulate an oil spill (refer to Table F.10):

- A regional dataset (HYDROMAP) that captures the general mesoscale circulation (HYCOM);
- A higher resolution dataset developed by RPS to capture the tidal circulation important in the coastal areas.

Table F.10: Current dataset details used for the modelling

Parameter	Global	Regional tidal
Name of Dataset	HYCOM (GLBy0.08/expt_93.0)	HYDROMAP
Owner/Provider	Naval Research Laboratory (USA)	RPS
Bathymetry	GEBCO	GEBCO
Wind Forcing	NAVGEM (USA)	No
Tides	No	Yes
Horizontal Grid Size	0.08° x 0.04°	~300m to 9km
Hindcast Period	2019 - 2023	Periodic tidal constituents' phase and amplitude
Output Frequency	Daily	30-minute processing

Global Current dataset – HYCOM analysis

Current data was obtained from the HYCOM + Navy Coupled Ocean Data Assimilation (NCODA) Global 1/12° analysis (Table F.10) which captures the oceanic large-scale tidal residual circulation. Details of the data assimilation procedure are described in Cummings and Smedstad (2013) and Cummings (2005). Forcing data for the model comes from the NAVy Global Environmental Model (NAVGEM). The analysis is composed of 3-D temperature, salinity, sea surface height, zonal velocity and meridional velocity fields. Ocean dynamics including geostrophic, and wind driven currents are reproduced by the model. The most recent version of the model is 'GLBu0.08/expt_19.1' which includes data from January 2019 to December 2023. However, as this version of HYCOM does not include tidal information, a separate model (HYDROMAP Tidal Model) was used to supplement HYCOM and generate tidal currents.

Tidal Currents – HYDROMAP Tidal Model

HYDROMAP, a hydrodynamic model (Table F.10) developed by RPS, was used to reproduce the local circulation due to tides around UK. It is a globally re-locatable hydrodynamic model (Isaji, et al., 2001a, 2001b) capable of simulating complex circulation patterns due to tidal forcing, wind stress, and freshwater flows. The framework used by HYDROMAP, employs a novel step-wise-continuous-variable-rectangular gridding strategy with up to six levels of resolution. The term "step-wise continuous" implies that the boundaries between successively smaller and larger grids are managed in a consistent integer step. This model has been applied in numerous sediment dispersion and transport studies in the U.S. and worldwide.

HYDROMAP can be used to make constant cyclical current fields for each component of the circulation separately. These cyclical current fields in the form of tidal ellipses are saved in CIR file. Once generated,

the CIR file can be combined with the HYCOM circulation to present a complete hydrodynamic dataset for the oil spill simulation.

Wind Data

Wind model output were obtained from the ECMWF Reanalysis Product for a 5-year period (2019 to 2023), as described in Table F.11. The ECMWF provides the ERA5 reanalysis product that includes wind hindcast data on a global scale. The data are generated using an atmospheric model with data assimilation and distributed on a grid with 0.25° horizontal resolution. ERA5 covers the period of January 1st, 1979, to present time. Gridded data products include a large variety of surface parameters, describing atmospheric as well as ocean-wave and land-surface conditions (Dee et al., 2011).

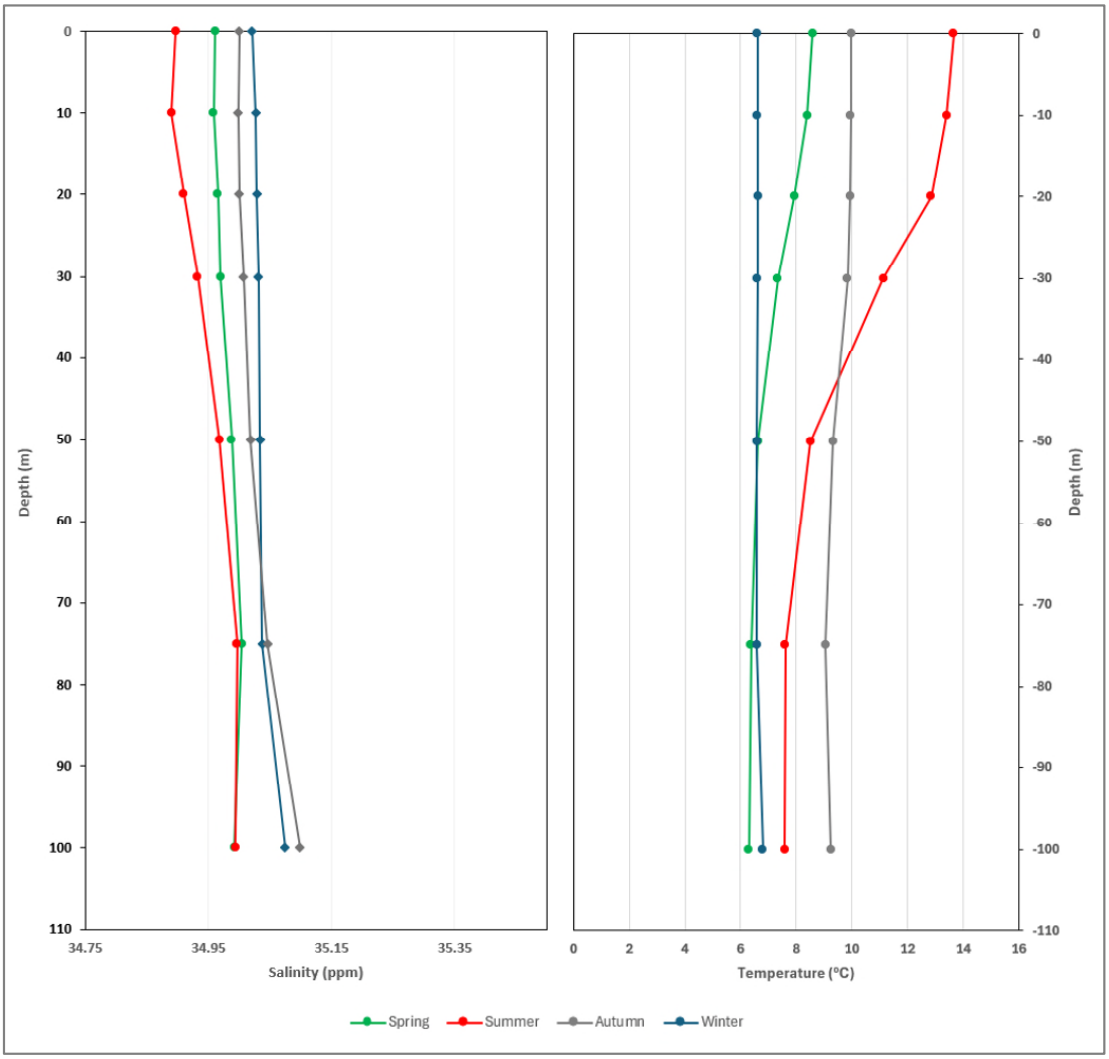
Table F.11: Wind dataset details used for the modelling

Name of Dataset	ERA5
Coverage	-20°E to 30°E and 40°N to 72°N
Owner/Provider	ECMWF
Horizontal Grid Size	0.25°x0.25°
Hindcast Period	2019 - 2023
Time Step	6-hour

Temperature and Salinity Data

Figure F.23 presents a salinity and temperature plot against depth for the modelled location per season.

Figure F.23: Salinity and Temperature plot against depth for each modelled season at the Kyla Development release location



F.6.2 Model Domain Setup

Bathymetry

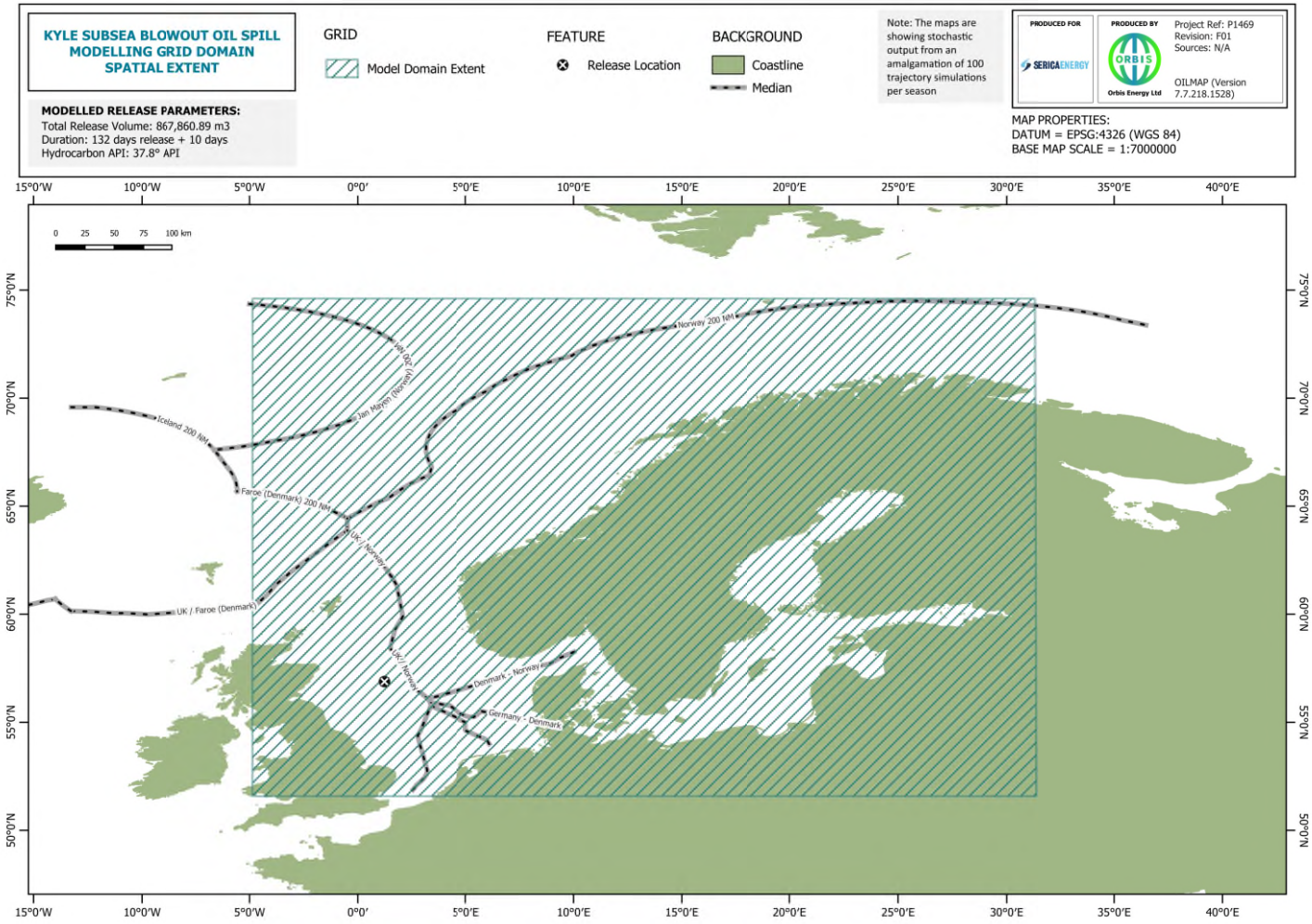
General Bathymetric Chart of the Oceans (GEBCO) ESRI ASCII files (GEBCO_2024 Grid) were retrieved from https://download.gebco.net and inputted into the OILMAP Land-Water domain grid.

The GEBCO_2024 Grid was released in July 2024. It provides global coverage of elevation data, in meters, on a 15 arc-second interval geographic grid and consists of 43200 rows x 86400 columns, giving 3,732,480,000 data points. The data values are pixel-centre registered i.e. they refer to elevations, in meters, at the centre of grid cells. The grid uses as a 'base' Version 2.6 of the SRTM15+ data set (Harper & Sandwell, 2024; Tozer et al., 2019) largely between latitudes of 50° South and 60° North. This data set is a fusion of land topography with measured and estimated seafloor topography. The SRTM15+ base grid has been augmented with the gridded bathymetric data sets developed by the four Seabed 2030 Regional Centres to produce the GEBCO_2024 Grid. The Regional Centres have compiled gridded bathymetric data sets, largely based on multibeam data, for their areas of responsibility. These regional grids were then provided to the Global Centre.

Model Domain Extent

The model domain extent area (including bathymetry, current and tidal, and wind data coverage) is shown in Figure F.24.

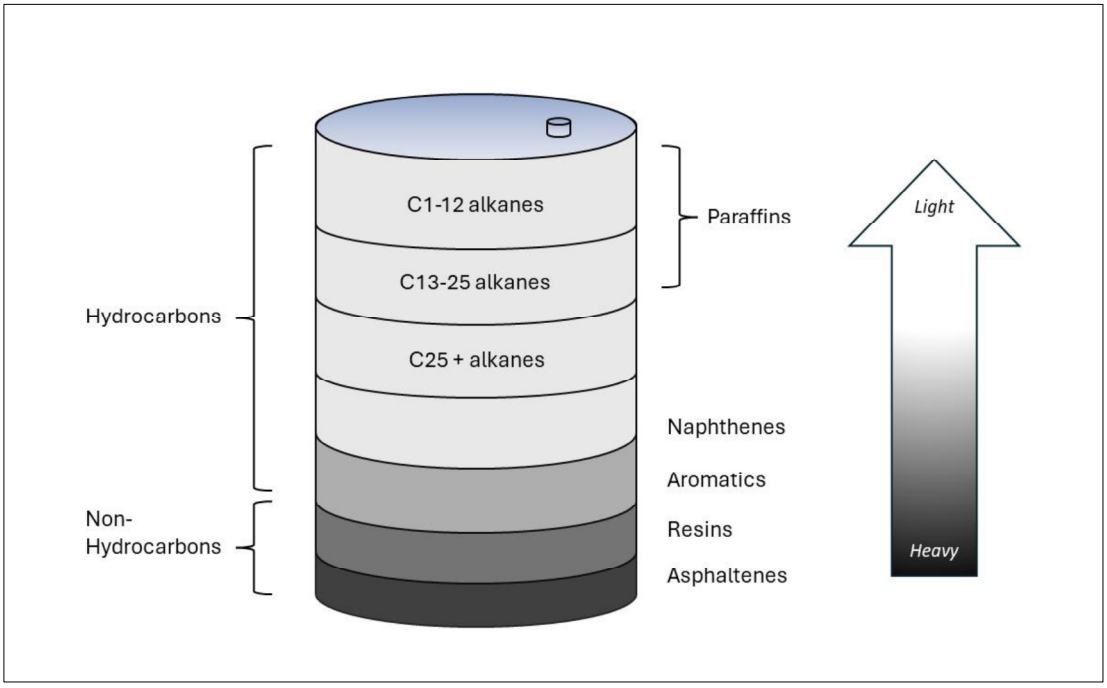
Figure F.24: Model Domain Extent



F.6.3 Hydrocarbon Characteristics

The components found in crude oil are classified into two main groups: hydrocarbons and non-hydrocarbons (refer to Figure F.25). If oil is rich in C1-12 alkanes, it is particularly light, as these are lighter components than the C25+ alkanes. Conversely, if oil contains high quantities of C25+ alkanes, resins and asphaltenes, it is heavy.

Figure F.25: The chemical composition of oil



The chemical composition of oil is important when predicting how it will break down or weather. For example, oil containing mostly light components is likely to lose a greater volume to evaporation than heavy oil. Oils with carbon chains exceeding 15 (C15+) cannot evaporate. Long chains (for example, C25+ alkanes) take a long time to degrade in the water column. Asphaltenes can increase the stability of oil, allowing it to take up water but preventing the oil and water emulsion from breaking down.

Ultimately, the fate of oil depends on its physico-chemical properties, which are accounted for in the in the modelling input data. OILMAP (Version 7.7) includes the most up-to-date oil database from RPS. This Master Database includes all the necessary oil property information to run the new oil spill model. The parameters stored in the oil database control the oil's spreading, evaporation, degradation and mousse formation during spill simulations. Any of the parameters can be changed and new oils can be added to the data base.

Oil Matching and Creation

The parameters described in Table F.12 represent the minimum data required to model a specific oil using OILMAP. Note that these properties are for dead oils and condensates (i.e., without gas). OILMAP does not evaluate dissolution, and so aromatic composition data are not needed for OILMAP.

The API gravity is the most important parameter for oil creation and matching. API Gravity, like specific gravity, is a ratio between the densities of oil and water. Unlike specific gravity, API gravity is only used to describe oil, which it characterises as follows:

- Light oil: API >31.1°
- Medium oil: API between 22.3° and 31.1°
- Heavy oil: API <22.3°
- Extra heavy oil: API <10°

API Gravity is converted to Specific Gravity using the following formula:

- API Gravity = (141.5 / Specific Gravity) – 131.5

An API of 10° is equivalent to water, so oils with an API above 10° will float on water while oils with an API below 10° will sink.

The reliability of oil behaviour can be improved by additional data described in Table F.13. When this additional data is available its inclusion can bolster model predictive power. Asphaltene, wax and resin content are used to predict if the oil will emulsify. If the oil is known to emulsify, these data are not necessary (assumptions may be made). Although proxies can be used when data are unavailable, reliance on such proxies will necessarily introduce additional assumptions and model reliability may decrease depending on the omitted data. The properties described in Table F.13 will augment the simulation of weathering and emulsion formation.

Table F.12: Minimum data required to run oil spill models in OILMAP

Property of Oil	Units	Common Range	Prediction for the Kyla Development (client supplied data)
API or Density at specified temperature	Grams per cubic centimetre (g/cm^3) or API	0.7-1.1 g/cm^3	Density from K14 Production Well Test. Crude Oil Sample: ACL 2005 0092b (3.04). • SG = 0.8365 @ 15°C • API = 37.8°
Dynamic viscosity at specified temperature	Centipoise (cP)	1 – 30,000 cP	Viscosity from K14 Production Well Test. Crude Oil Sample: ACL 2005 0092b (3.04). • 11.053 cP @ 20°C
Boiling Curve (True Boiling Point Distribution)	Fraction by mass or volume @ °C or °F	0 – 0.99	Unknown
Does the oil emulsify?	Yes or No	Yes or No	No

Table F.13: Other useful data to run oil spill models in OILMAP (to improve reliability, not mandatory)

Property of Oil	Units	Common Range	Prediction for the Kyla Development (client supplied data)
A second Density at a second specified temperature	g/cm^3 or API	0.7-1.1 g/cm^3	Unknown
A second Viscosity at a second specified temperature	Centipoise (cP)	1 – 30,000 cP	Unknown
Maximum Water Content of emulsions	Percentage	0 – 80%	Oil not expected to form emulsions.
Interfacial Tension (IFT): oil-brine and/or oil-fresh water	Dynes (mN/m)	0 – 50	Unknown
Pour Point	°C	-63 – >5 °C (semi-solid)	Pour point from K14 Production Well Test. Crude Oil Sample: ACL 2005 0092b (3.04).

Property of Oil	Units	Common Range	Prediction for the Kyla Development (client supplied data)
			• +3°C
Asphaltene content	Concentration percentage	0 – 25 %	Asphaltene content C7 (% wt) from 29/2c-8z Exploration Well Test. Crude Oil Sample: ACL 971294. • 0.15 %
Resin Content	Concentration percentage	0 – 25 %	Unknown
Wax Content	Concentration percentage	0 – 12 %	Wax content (% wt) from 29/2c-8z Exploration Well Test. Crude Oil Sample: ACL 971294. • 7 %

The main physical properties that affect the behaviour and the persistence of an oil spilled at sea are specific gravity / API, distillation characteristics, vapour pressure, viscosity and pour point. All are dependent on chemical composition, such as the proportion of volatile components and the content of asphaltenes, resins and waxes. Of note, oil emulsification will generally only take place if the asphaltene content is greater than 0.5 %. Importantly, the formation of water-in-oil emulsions reduces the rate of weathering processes and is the main reason for the persistence of light and medium oils on the sea surface and shoreline.

The hydrocarbon properties expected from the proposed Kyla Development are anticipated to resemble a ITOPF Group 2 crude oil that does not form a stable emulsion.

The 'Chayvo #6 Crude' analogue has been selected as a suitable proxy oil for the proposed Kyla Development because it is compositionally a non-emulsifying crude oil (refer to Table F.14 for the key properties). For the purposes of the Kyla Development oil spill modelling study, the analogue has been amended where data is available (refer to Table F.12 and Table F.13) to fine tune the API gravity / density, pour point and wax content parameters. The amended analogue is shown in Table F.14.

Table F.14: Key properties for the 'Chayvo #6 Crude' proxy oil analogue

Oil Name (Analogue)	API Gravity	Density	Oil-Seawater Interfacial Tension	Viscosity 1	Viscosity 2	Pour Point	Percent water when fully emulsified as mousse	Oil Stability Class (emulsion)	Distillation Data (fraction)				Saturate, Aromatic, Resin and Asphaltene (SARA)				Wax Content
									Boiling Points: < 180°C	Boiling Points: 180°C – 264°C	Boiling Points: 265°C - 380°C	Distillation Sum	Saturate Content	Aromatics Content	Asphaltene Content	Resin Content	
Chayvo #6 Crude (ITOPF Group 2)	38.1	0.8345 g/cm³ @ 25°C	15.8 dyne / cm	19 cP @ 0°C	4 cP @ 15°C	-4	0.2 %	Un-Stable	Total Hydrocarbon = 0.230000	Total Hydrocarbon = 0.261880	Total Hydrocarbon = 0.188520	0.680400	87.86	8.59	0.15	3.4	5%
Amended 'Chayvo #6 Crude' Analogue for the Kyla Development Well (ITOPF Group 2)	37.8	0.8365 g/cm³ @ 15°C	15.8 dyne / cm	19 cP @ 0°C	4 cP @ 15°C	3	0.2 %	Un-Stable	Total Hydrocarbon = 0.230000	Total Hydrocarbon = 0.261880	Total Hydrocarbon = 0.188520	0.680400	87.86	8.59	0.15	3.4	7%

Note 1: Amended oil analogue properties in red.

F.6.4 Declining Flow Rate

Figure F.26 shows the high case open hole flow rate from the Kyla K14 well for 132 days. The worst-case oil flow rate starts at 7926.70 m^3/day (49,856.60 bbl/day) on day 1 of the spill scenario and declines to 5223.38 m^3/day (32,853.50 bbl/day) after 132 days. The total cumulative release of oil after 132 days is 867,860.89 m^3 (5,458,587.90 bbl).

Figure F.26: Declining flow rate for the Kyla K14 Well (Reservoir Case = High) (132 days)

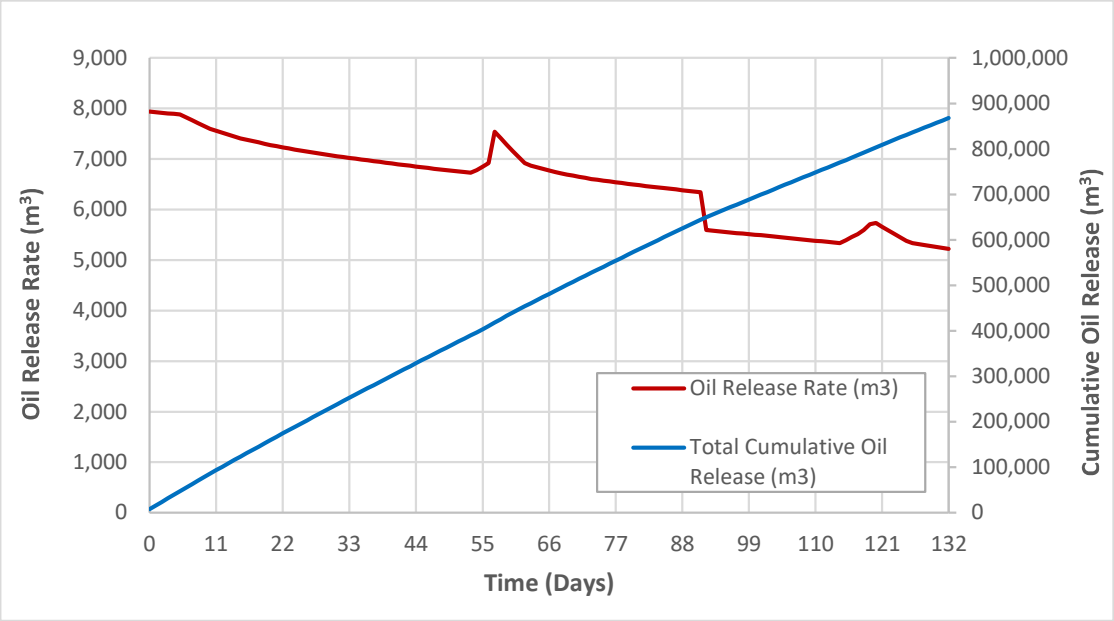


Table F.15 displays the declining flow rate data at 24-hour intervals which was input into the OILMAP modelling software.

Table F.15: Variable Flow Rate (VFL file) Model Input Data

Time (Hours)	Declining flow rate for the K14 well (Reservoir Case = High) (132 days) (bbl)
24.00	49856.60
48.00	49784.50
72.00	49712.30
96.00	49640.00
120.00	49567.60
144.00	49211.30
168.00	48846.60
192.00	48484.20
216.00	48124.20
240.00	47774.30
264.00	47537.20
288.00	47301.20
312.00	47066.30
336.00	46832.40
360.00	46599.70
384.00	46431.40

Time (Hours)	Declining flow rate for the K14 well (Reservoir Case = High) (132 days) (bbl)
408.00	46264.20
432.00	46097.60
456.00	45931.50
480.00	45766.00
504.00	45622.10
528.00	45483.80
552.00	45346.00
576.00	45208.50
600.00	45071.40
624.00	44940.80
648.00	44824.90
672.00	44709.20
696.00	44593.80
720.00	44478.70
744.00	44363.90
768.00	44263.20
792.00	44163.80
816.00	44064.60
840.00	43965.50
864.00	43866.70
888.00	43767.60
912.00	43668.40
936.00	43569.50
960.00	43470.80
984.00	43372.30
1008.00	43275.40
1032.00	43183.80
1056.00	43092.30
1080.00	43001.10
1104.00	42910.10
1128.00	42819.20
1152.00	42735.00
1176.00	42654.30
1200.00	42573.80
1224.00	42493.50
1248.00	42413.30
1272.00	42333.30
1296.00	42650.50
1320.00	43081.40
1344.00	43516.20

Time (Hours)	Declining flow rate for the K14 well (Reservoir Case = High) (132 days) (bbl)
1368.00	47442.00
1392.00	46629.30
1416.00	45830.30
1440.00	45044.00
1464.00	44271.80
1488.00	43512.80
1512.00	43203.80
1536.00	43001.40
1560.00	42800.00
1584.00	42599.80
1608.00	42400.60
1632.00	42229.00
1656.00	42090.60
1680.00	41952.70
1704.00	41815.40
1728.00	41678.60
1752.00	41542.40
1776.00	41433.50
1800.00	41334.80
1824.00	41236.50
1848.00	41138.40
1872.00	41040.60
1896.00	40943.90
1920.00	40851.50
1944.00	40759.40
1968.00	40667.50
1992.00	40575.90
2016.00	40484.60
2040.00	40398.30
2064.00	40316.50
2088.00	40235.00
2112.00	40153.70
2136.00	40072.70
2160.00	39991.90
2184.00	39897.70
2208.00	35176.20
2232.00	35100.30
2256.00	35024.70
2280.00	34949.20
2304.00	34876.90

Time (Hours)	Declining flow rate for the K14 well (Reservoir Case = High) (132 days) (bbl)
2328.00	34809.90
2352.00	34743.10
2376.00	34676.50
2400.00	34610.10
2424.00	34543.80
2448.00	34477.60
2472.00	34397.90
2496.00	34318.60
2520.00	34239.50
2544.00	34160.60
2568.00	34082.00
2592.00	34004.10
2616.00	33929.10
2640.00	33854.30
2664.00	33779.70
2688.00	33705.40
2712.00	33631.20
2736.00	33557.30
2760.00	33921.50
2784.00	34302.70
2808.00	34687.90
2832.00	35212.00
2856.00	35907.10
2880.00	36070.80
2904.00	35608.30
2928.00	35153.20
2952.00	34705.20
2976.00	34264.30
3000.00	33830.30
3024.00	33550.60
3048.00	33432.20
3072.00	33314.40
3096.00	33197.20
3120.00	33080.70
3144.00	32964.70
3168.00	32853.50
Cumulative Oil Release	**5,458,587.90**

Appendix G: Kyla Production Profiles

This appendix presents the range of potential reserve volumes for Kyla (oil, gas and water production figures) as follows:

- Table G.1 – P10, High case (based on a one well development scenario)
- Table G.2 – P50, Mid case (based on a one well development scenario)
- Table G.3 – P90, Low case (based on a one well development scenario)

As a comparison, Table G.4 presents the Kyla oil and gas production figures as presented in the Field Development Plan (FDP). Where the FDP data has been converted for use in this ES, the following conversion factors have been used:

- 1 m^3 = 6.2898 bbl
- 1 m^3 = 0.83432 tonnes
- 1 m^3 = 3.53147 * 10-5 mmscf

Table G.1: Kyla Oil, Gas and Water Production Volumes, High case [1,2]

Year	Oil (tonnes/d)	Oil (m^3/d)	Oil (bbl/d)	Gas (m^3/d)	Gas (MMscf/d)	Water (m^3/day)	Water (bbl/d)
2028	416	498	3,133	66,564	2.4	2	14
2029	928	1,112	6,997	144,720	5.1	11	69
2030	795	953	5,997	120,940	4.3	64	403
2031	636	762	4,794	95,705	3.4	155	972
2032	541	649	4,080	81,265	2.9	224	1409
2033	472	566	3,562	70,684	2.5	261	1644
2034	431	517	3,249	64,194	2.3	296	1862
2035	400	480	3,018	59,288	2.1	333	2097

[1] P10 (High case) is defined as the highest estimate of recoverable and/or potentially recoverable volumes from the Kyla Development based on a one well development scenario. There is a 10% probability that recovered volumes will meet or exceed the high case estimate.
[2] Production values presented in this table have been rounded up to the nearest integer. All calculations in Appendix E were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

Table G.2: Kyla Oil, Gas and Water Production Volumes, Mid case [1,2]

Year	Oil (tonnes/d)	Oil (m^3/d)	Oil (bbl/d)	Gas (m^3/d)	Gas (MMscf/d)	Water (m^3/day)	Water (bbl/d)
2028	383	459	2,885	60,092	2.1	2	14
2029	722	865	5,442	110,471	3.9	13	83
2030	604	724	4,555	90,770	3.2	41	259
2031	459	550	3,462	67,981	2.4	111	695
2032	364	436	2,743	53,565	1.9	176	1,105
2033	301	361	2,269	44,195	1.6	212	1,332
2034	267	320	2,015	39,176	1.4	242	1,522
2035	249	298	1,875	36,355	1.3	271	1,704

[1] P50 (Mid case) is defined as the best estimate of recoverable and/or potentially recoverable volumes from the Kyla Development based on a one well development scenario. There is a 50% probability that recovered volumes will meet or exceed the mid case estimate.
[2] Production values presented in this table have been rounded up to the nearest integer. All calculations in Appendix E were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

Table G.3: Kyla Oil, Gas and Water Production Volumes, Low case [1,2]

Year	Oil (tonnes/d)	Oil (m^3/d)	Oil (bbl/d)	Gas (m^3/d)	Gas (MMscf/d)	Water (m^3/day)	Water (bbl/d)
2028	128	153	963	20,626	0.7	3	19
2029	264	317	1,992	42,467	1.5	7	43
2030	248	298	1,873	39,841	1.4	7	44
2031	239	286	1,799	38,228	1.4	7	46
2032	237	284	1,787	37,923	1.3	8	50
2033	230	276	1,734	36,741	1.3	9	55
2034	230	276	1,733	36,680	1.3	10	65
2035	233	279	1,758	37,201	1.3	13	82

[1] P90 (Low case) is defined as the lowest estimate of recoverable and/or potentially recoverable volumes from the Kyla Development. There is a 90% probability that recovered volumes will meet or exceed the low case estimate.
[2] Production values presented in this table have been rounded up to the nearest integer. All calculations in Appendix E were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

Table G.4: Kyla Oil and Gas Production Volumes (Low, Mid and High case) as reported in the FDP

Kyla	Low case				Mid case				High case			
1 Well	Oil		Gas		Oil		Gas		Oil		Gas	
Year	*Kte*	*mmstb*	*ksm³*	*bscf*	*kte*	*mmstb*	*ksm³*	*bscf*	*kte*	*mmstb*	*ksm³*	*bscf*
2028	47	0.35	7,549	0.27	140	1.06	21,994	0.78	152	1.15	24,362	0.86
2029	96	0.73	15,500	0.55	263	1.99	40,322	1.42	339	2.55	52,823	1.87
2030	91	0.68	14,542	0.51	221	1.66	33,131	1.17	290	2.19	44,143	1.56
2031	87	0.66	13,953	0.49	168	1.26	24,813	0.88	232	1.75	34,932	1.23
2032	87	0.65	13,880	0.49	133	1.00	19,605	0.69	198	1.49	29,743	1.05
2033	84	0.63	13,410	0.47	110	0.83	16,131	0.57	172	1.30	25,799	0.91
2034	84	0.63	13,388	0.47	98	0.74	14,299	0.50	157	1.19	23,431	0.83
2035	85	0.64	13,578	0.48	91	0.68	13,270	0.47	146	1.10	21,640	0.76
Total	661	4.98	105,801	3.74	1223	9.22	183,565	6.48	1687	12.72	256,874	9.07